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Advances in Basement Technology

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Prepared for
The Research Division
Policy Development and Research Section
Canada Mortgage and Housing Corporation

by

The Becker Engineering Group
Windsor, Ontario
in Association with

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Canada Mortgage and Housing Corporation, the Federal Government's housing agency, is responsible for administering the National Housing Act.

This legislation is designed to aid in the improvement of housing and living in Canada. As a result, the Corporation has interests in all aspects of housing and urban growth and development.

Under Part V of this Act, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing related fields, and to undertake the publishing and distribution of the results of this research. CMHC therefore has a statutory responsibility to make widely available, information which may be useful in the improvement of housing and living conditions.

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FOREWORD

An advisory committee provided CMHC and the consultants with a broad range of information and opinions from which the study has benefitted greatly.

To the avant–guard builder, the Vanguard Systems illustrated in the report may not seem to be much of an advance. To the more conservative builder they present a significant shift in building practice. What is presented is a compromise, but one which we believe constructively challenges the industry's status quo.

The report emphasizes the "house as a system" approach as being necessary for continued development of the house–building practice. However, there are elements of the basement–system which are still inadequately investigated within this report. For example, providing for a free flow of air from the zone outside basement walls to the zone beneath the slab is a trade–off between drainage needs, soil–gas control, quality–of–construction expectations and building costs. To evaluate the trade–offs on the aforementioned and other issues, a developmental phase is called for. This will allow building practice guidelines and code change recommendations to be made with confidence. Of particular concern is the risk of flooding. Before there can be further encouragement to use basement space for living area, the engineering of drainage systems must be improved to be extremely reliable. A peer review of this report will be conducted to ensure our efforts are kept on track, particularly as the views of some advisory committee members differed as to the report's completeness and the degree to which it lives up to its title of "Advances in Basement Technology".

The developmental phase then, will follow the lead of this study. This will further bridge the interests of consumers, builders, building researchers and building code authorities. A further step to affordable foundations for houses.

ABSTRACT:

This is a proactive study that is targetted at a broad readership. It sets a framework within which to evaluate basement advances in the context of building science, functionality, produceability, reliability, affordability and marketability.

Historical perspectives on Canadian basements are reviewed, issues fundamental to producing liveable basements are discussed and the building science requirements that must be respected by the basement system are underscored.

The results of this study suggest that a rationalization of the traditional elements of the basement system is the key that can unlock major advances in basement technology. A number of rationalized, Vanguard basement systems are presented and evaluated against a Benchmark, site–cast concrete basement.

Knowledge gaps, research needs and development opportunities that were identified during the course of this study are also presented in this report.

KEY WORDS:

Liveable basements, basement systems, innovative technologies, functionality, produceability, reliability, affordability, marketability, rationalization, vanguard systems, implementation, knowledge gaps, research, development, implementation.

ACKNOWLEDGEMENTS:

The study team would like to acknowledge the significant contributions made to this study by the research staff of the CMHC, the NRC, the IRC; representatives of the Canadian Portland Cement Association, the Canadian Wood Council, the Society of Plastics Industries, Dofasco Incorporated, the Canadian Home Builders Association and Regional Realty; and others who participated actively in this study and submitted comments on various sections of this report. The time they devoted to this effort attests to the importance they place on the study topic.

The valuable contributions of Prof. John Timusk of the University of Toronto, who was retained as a specialist subconsultant by the CMHC for this study, is also gratefully acknowledged.

The formidable task of orchestrating this study, directing the study team and soliciting the input of so many representatives of the housing industry was shouldered by Messrs. Peter Russell and Al Houston of the Research Division of the CMHC. Their contributions towards this study were invaluable to the study team and therefore warrant special acknowledgement.

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1.0 INTRODUCTION

1.1 GENERAL

Home buyers in Canada continue to show a strong preference for houses with basements. A recent marketing survey by the National Association of Home Builders indicates that fully two–thirds of new home buyers (and 75% of first–time home buyers) prefer houses with basements. Yet, home buyers frequently complain of problems associated with basements.

Experience has shown that under the best conditions, when sound engineering is rigorously combined with careful construction practices and a proper selection of construction materials, basements can be produced that are reasonably problem–free and suitable for living space. However, many basements are not built with such rigorous care. Basements have therefore retained a nagging reputation for being damp, dark and dingy places that are largely unfit for comfortable habitation.

While significant improvements have been made in the design and construction of basements in recent years, serious problems persist that prevent basements from being broadly and fully utilized as desirable living space. The challenge that faces all concerned with the quality of housing in Canada is to advance basement technology to the extent required to ensure that basements can routinely be built to offer affordable, trouble–free, living space. Since basement areas of new houses in Canada likely constitute between 25 and 35 percent of the total potential living space in single–family residential dwellings, advancing the technology of basement construction would significantly improve the quantity, quality and affordability of dwelling space in Canada.

The technical issues that must be addressed to advance basement technology, although generally understood, are complex. Advances in basement technology require a strong interplay between various engineering and construction disciplines. A proposed improvement in one area of basement technology must be carefully scrutinized to ensure that an advancement in one area does not adversely effect some other technical requirement.

Traditional basements built in Canada have evolved through progressive code changes, to a complex layered system. Footing tiles, drainage layers, dampproofing, insulation, vapour barriers and finishes have been added to the basement system in an attempt to meet specific technical requirements. Recent concerns over radon and other soil–gases will likely necessitate adding further elements to the basement system in the near future.

The challenge that faces the housing industry in Canada is to advance basement technology through innovations in materials, systems and construction practices. The primary focus of this study is to identify major advances that promise to improve the quality, performance and liveability of residential basements.

1.2 STUDY TEAM

The prime consultant for this study was N.K. Becker & Associates Ltd., a member company of the Becker Engineering Group. However, a substantial portion of this study was carried out by Scanada Consultants Ltd. Mr. David Eyre of the Saskatchewan Research Council was a specialist subconsultant to N.K. Becker & Associates Ltd.

The study team was guided in its research by representatives of the Housing Research Community who attended a Symposium sponsored by the CMHC in Ottawa on 20, 21 September 1988 and also by Professor John Timusk of the University of Toronto who was retained for this purpose, directly by the CMHC.

2.0 PURPOSE AND SCOPE

2.1 OBJECTIVES

The objectives of this study were to define a framework within which to evaluate advances in basement technology; to review current basement construction practices and problems; to study advances that are being made in this technology; to identify and describe technological concepts that hold promise of improving the functionality, affordability and performance of basements; and to identify knowledge gaps and research needs that should be addressed to advance basement design.

Because of the diversity of Canadian home buyer preferences, vast differences in regional climates and conditions, and variations in the availability of specific materials and skilled trades in Canada, this study was not intended to search out a single "best technology". To the contrary, this study was prefaced on the knowledge that no single technology could possibly be "ideal" for all basements across Canada. Rather, the purpose of this study was to identify and evaluate a number of Vanguard basement systems that through continued research, development and refinement hold significant promise for improving the liveability of basements and therefore the quality and affordability of housing across Canada.

The terms of reference for this study were not rigidly prescribed by the CMHC. Rather, they were periodically reviewed and refined, through input from invited representatives of the housing industry. It was intended by the CMHC that this study be targetted at the broadest possible readership. This posed a significant challenge to the study team who realized that in attempting to interest everyone, they risked satisfying no one.

It is hoped that this study will provide both a framework and a focus for collaborative research and development efforts that will hasten the implementation of significant advances in basement technology, by the diverse sectors of the housing industry in Canada.

3.0 STUDY RESULTS

In keeping with the proactive nature of this study, the CMHC convened a two day symposium at its commencement that was attended by invited representatives of the housing research community; the concrete, wood, steel and plastics industries; the Canadian Home Builders Association; and others with specific interests in advancing basement technology in Canada. The purpose of this seminar was to solicit their participation in setting the focus and providing continuing direction for this study. A summary of the presentations made at this seminar, which was held in Ottawa on 20 and 21 September 1988, is presented in Appendix A of this report.

The challenges that were posed merely in attempting to define reasonable limits for the depth and breadth of this study are evidenced by the diverse concerns and interests expressed by the participants who attended this seminar. Some focused on the need for advancing the functional potential of basements; others stressed the technological need for further scientific advancements; and others yet challenged the study team to concentrate on practical advancements that would be of tangible and immediate benefit to the building industry.

This seminar served to underscore the fact that new materials, methods or systems suggested for advancing basement technology cannot be evaluated properly, solely within the confines of building science. They must be evaluated within the broader context of functionality, produceability, affordability, serviceability, reliability and marketability.

The first task of the study team was therefore to establish a proper framework within which to evaluate advances in basement technology. This entailed reviewing the historical perspectives of basements in Canada and then examining the many issues that must be considered in any attempt to improve basements. So as not to overwhelm the reader, discussions on these fundamental issues have been relegated to the Appendix of this report. However, since they are of underlying importance to this study, an overview is presented below.

3.1 HISTORICAL PERSPECTIVES

Canada's diverse geography, geology, climate and ethnicity have lead to some regional and local differences in Canadian housing. However, because of Canada's short history, these differences are neither deep–rooted nor profound. Approximately 60 percent of Canadians are currently housed in single–family, detached dwellings, most of which have at least a partial basement. Half of this housing stock is less than 25 years old and approximately 80 percent is located in urban settings concentrated within Canada's southernmost latitudes.

Fully two–thirds of Canadian home buyers surveyed recently, prefer houses with basements. Traditionally houses with basements also have a higher resale value.

Basements in Canada are produced very efficiently, consuming only about 100 man–hours of labour for basic excavating, footings, walls and backfill. But they can be troublesome. Surveys conducted for the Housing & Urban Development Association of Canada in 1975 confirmed that at that time problems with basements accounted for nearly 50 percent of all complaints from new home buyers.

Currently, over 90 percent of all basements in Canada are being constructed of site–cast concrete. While block masonry basements were popular in the first half of the century, a shortage of skilled masons and increasing labour costs have substantially reduced the market for block masonry basement walls in most regions of Canada. Preserved wood basement walls which were introduced in Canada commercially in the 1970's now account for approximately 7 percent of the total market. They are especially popular in the Prairie Provinces.

Prior to the publication of the first National Building Code in 1941, many basements in Canada were built without footing tiles, dampproofing or even concrete floors. The improved quality of basement space that accompanied these and subsequent building Code requirements over the last 50 years has dramatically improved the quality and expanded the functionality of basements from mere utility space to more useable living space. This trend is continuing and has heightened research efforts directed at improving the performance, liveability and affordability of Canadian basements.

3.2 ISSUES FUNDAMENTAL TO IMPROVING BASEMENTS

For the purpose of this study, the many factors fundamental to improving basements have been categorized into Functional Issues, Engineering Issues, Builder Issues and Marketing Issues. These are explored in considerable detail in Appendix C of this report. A summary discussion of each is presented below.

3.2.1 Functional Issues

The function of basements has changed dramatically since the turn of the century. Early cellars were used primarily for the storage of food produce. The function of cellars expanded rapidly in the early part of the century with the advent of central heating systems. The basement proved to be not only an ideal location for bulky heating equipment, but also for the storage of fuel such as wood or coal. The improved quality of basement space that resulted from the introduction of basic footing tiles, dampproofing and concrete floors in the middle of this century, soon expanded the function of basements further to include utility areas, laundry rooms, work rooms and storage space.

In the post baby–boom period of the 1950's, families with young children began to convert basement areas into recreational space and additional bedrooms. This conversion of basements to living space was facilitated in part by the development of more compact oil and gas–fired central heating systems that could be accommodated within smaller areas of the basement. By 1970, approximately 8 percent of all new houses were built with at least a partially finished basement and the majority of others were readily finishable by the home owner.

The function of basements in Canada is still changing. The escalating cost of houses in urban areas has stimulated interest in "convertible basements" that can be built to be altered, to best suit the changing life–cycle needs of a family. Unfinished, such convertible basements can minimize the initial cost of a new house, while affording a home owner the option of converting such basement space to living space or to an auxilliary apartment in full compliance with Codes and local by–laws, as and when required to accommodate a growing family or to generate rental income.

The predominant trend in the function of Canadian basements is definitely towards "liveable space", comparable in quality to that of the upper storeys of a house. For basements to satisfy this function, further advancements in basement technology will be required to meet the quality, performance and affordability criteria expected by home owners.

3.2.2 Engineering Issues

The primary engineering criteria that must be satisfied for the production of liveable basement space are listed below:

a) Structural adequacy and durability.
b) Moisture exclusion (liquid and vapour).
c) Energy efficiency.
d) Control of construction water.
e) Exclusion of radon and other soil–gases.
f) Affordability.
g) Serviceability.

Other engineering factors that must also be considered in the design of liveable basements include ease of access to the upper floors; safety of egress; the quality of the finishes; noise attenuation; improved natural lighting; and the provision of adequate utilities.

The fundamental building science requirements that must be respected in the production of liveable basements are discussed in Section 3.3 of this report. The broader engineering issues are discussed in Appendix C.

3.2.3 Builder Issues

The issues fundamental to improving basements that concern builders include the following:

a) Capital investment.
b) Competitive pricing.
c) Simplicity of construction.
d) Speed of construction.
e) Availability of materials, equipment and tradesmen.
f) Year–round construction.
g) Warranty commitment of suppliers.
h) Adaptability to custom–housing.
i) Call–backs.

True advancements in basement systems viewed from the perspective of the builder must necessarily be evaluated within the broadest context of produceability, affordability, marketability and reliability. Advances in basement technology that require major capital investments by builders will likely be adopted only by major builders. The housing industry in Canada is not only volatile but also risky. Consequently, capital intensive ventures are likely to be viewed with skepticism; particularly by small builders.

The availability and cost of materials, equipment and labour is always an important consideration in the adoption of new technology by home builders in Canada. Advances in basement technology predicated on the use of non–traditional materials, specialized labour or expensive equipment will also be an impediment to implementation by the industry.

In recent years, home builders in Canada have been expected to provide more comprehensive warranties for new houses. Consequently, builders are apt to be reluctant to utilize materials, methods or systems that are not totally proven and fully warrantied by their proponents. However, new technologies that promise to simplify and speed construction, to be more reliable and require fewer call--backs have traditionally been well received by builders.

3.2.4 Marketing Issues

Home buyers in Canada have come to expect a wide variety of choices in architectural housing styles and good value for their money. In recent years, the price of an average new house has escalated above the affordability of many Canadian families. Consequently, any proposed advancement in basement technology must be analyzed both on the basis of architectural adaptibility and perceived value.

New or improved materials, methods or systems proposed for improving the quality and performance of basements must be both marketable and affordable to Canadian home buyers.

3.3 BUILDING SCIENCE REQUIREMENTS

The broader engineering issues fundamental to advancing the quality and performance of basements are discussed in detail in Appendix C of this report. However, the specific building science criteria which advances in basement technology must respect, warrant special consideration and therefore are summarized below.

The terms of reference for this study did not extend to establishing quantative building science criteria for liveable basements. In some cases, quantative criteria or threshhold criteria are already regulated by Canadian Codes and standards. In other cases (e.g. allowable soil–gas concentrations) they are not. Yet building science criteria are ever changing and no "ultimate criteria" for evaluating future advances in basement technology are ever likely to evolve.

For the purpose of this study, it has been assumed that the building science criteria adopted for liveable basements should be capable of matching those adopted from time to time, for living space on the upper levels of a house.

Structural adequacy which is discussed in detail in Appendix C of this report, is obviously an essential requirement for any basement system. Other building science considerations that are perhaps less obvious, but equally fundamental to producing high quality, liveable basements, are summarized below:

A. Compatibility with In Situ Soils

As subsurface structures, basements must be compatible with the insitu soils in which they are built. Basements can affect not only the stresses in subsurface soils, but also the moisture content and temperatures within these soils. Basements built in "normal average soils" (as defined in the National Building Code) generally do not warrant special design consideration. However, the compatability of basements with problem soils (e.g. unstable soils, expanding clays, permafrost soils, etc.) cannot be overlooked.

B. Separating the Indoor from the Outdoor Environment

This entails isolating the below–grade living space from the following external factors:

1.1 Controlling Water

a) Prevent any head of water above the basement floor; provide drainage away from the floor and the wall base, and,

b) Provide free drainage of the soil, over the full height of the basement wall; preferably with little or no contact between water and the structural wall, and connected freely to (a) above. (Much of the water can and should be removed by surface drainage, which is usually a matter of grading).

c) Provide a barrier to the entry of liquid water where it does contact the basement structure and/or let the structure itself be such a barrier, and,

d) At joints or details where water may not be completely shed at the exterior of such a barrier, provide vented (i.e. pressure–equalized) drainage channels back to the external drainage path. This applies to the above–grade structure as well.

e) Minimize construction moisture and/or avoid entrapment of such water to prevent fungal growth and/or deterioration of structural materials and interior finishes.

1.2 Controlling Water Vapour

a) Minimize the water vapour pressure by keeping the soil cold. (Which follows in any case from heat flow control, 1.4).

b) Control mass transfer as per 1.3.

1.3 Controlling Soil–Gases

a) Provide an impervious barrier enveloping the entire basement structure below grade and maintaining its integrity at sumps, drains and other penetrations, and/or

b) Provide a continuous "airway" jacket enveloping the entire basement structure below–grade, capable of being depressurized (mechanically and/or passively) as and when required, and bounded on the basement side with a relatively impervious barrier or structure. (Such a jacket space may also serve as the enveloping drainway described in a) and b) of 1.1).

1.4 Controlling Heat Flow

a) Provide resistance to heat flow of an amount and coverage dictated by economics and comfort.

(Apart from heat flow, other factors impinge on the material and placement choices in thermal insulations. Where the thermal insulation is on the wall's exterior and may serve also as a portion of the drainway and airway, its material properties are dictated in part by those functions set out in 1.1, 1.2 and 1.3. Where it is on the interior, it must extend completely to the basement floor and related details must not allow "bypass" heat flows via air convective loops or leaks. The following points also impinge on the matter of insulation material and location).

b) Provide a barrier to air flow (infiltration and exfiltration) to a degree dictated by economics, comfort and the avoidance of condensation.

1.5 Avoiding Excessive Concealed Condensation

a) Keep the structure warm, above the dew point of the indoor air all or enough of the time in winter and summer (i.e. place much or all of the insulation outside the wall structure). If that approach is not followed;

b) Provide a complete vapour barrier on the warm side of at least that portion of the insulation and structure that operates below the indoor dew point temperature for significant periods and,

c) Avoid entrapment of condensate (or water of whatever origin) especially in locations or materials where it can degrade the materials or promote fungal growth that can adversely affect the indoor air quality.

C. Control of Costs for Liveable Space Below Grade

These considerations may be less fundamental than the foregoing, in the building science sense, but they are indeed fundamental in the engineering sense of applying science economically. They are stated in general terms, again to aid in assessing and comparing system advances. The design so chosen must enable the following to be achieved:

1.6 Control of First Costs

a) Minimize labour; particularly on site and skilled labour.

b) Minimize weather effects to facilitate year–round building.

c) Minimize on site construction time.

d) Minimize on site plant.

e) Minimize material and component costs.

1.7 Control of Life–Cycle Costs

a) Maximize the durability of all components and functions, with minimal maintenance.

b) Avoid excessive annual heating/cooling costs.

c) Provide an integral finish or alternatively a sound substrate for robust, easily maintainable interior finish as well as above–grade exterior finish.

3.4 THE BENCHMARK BASEMENT

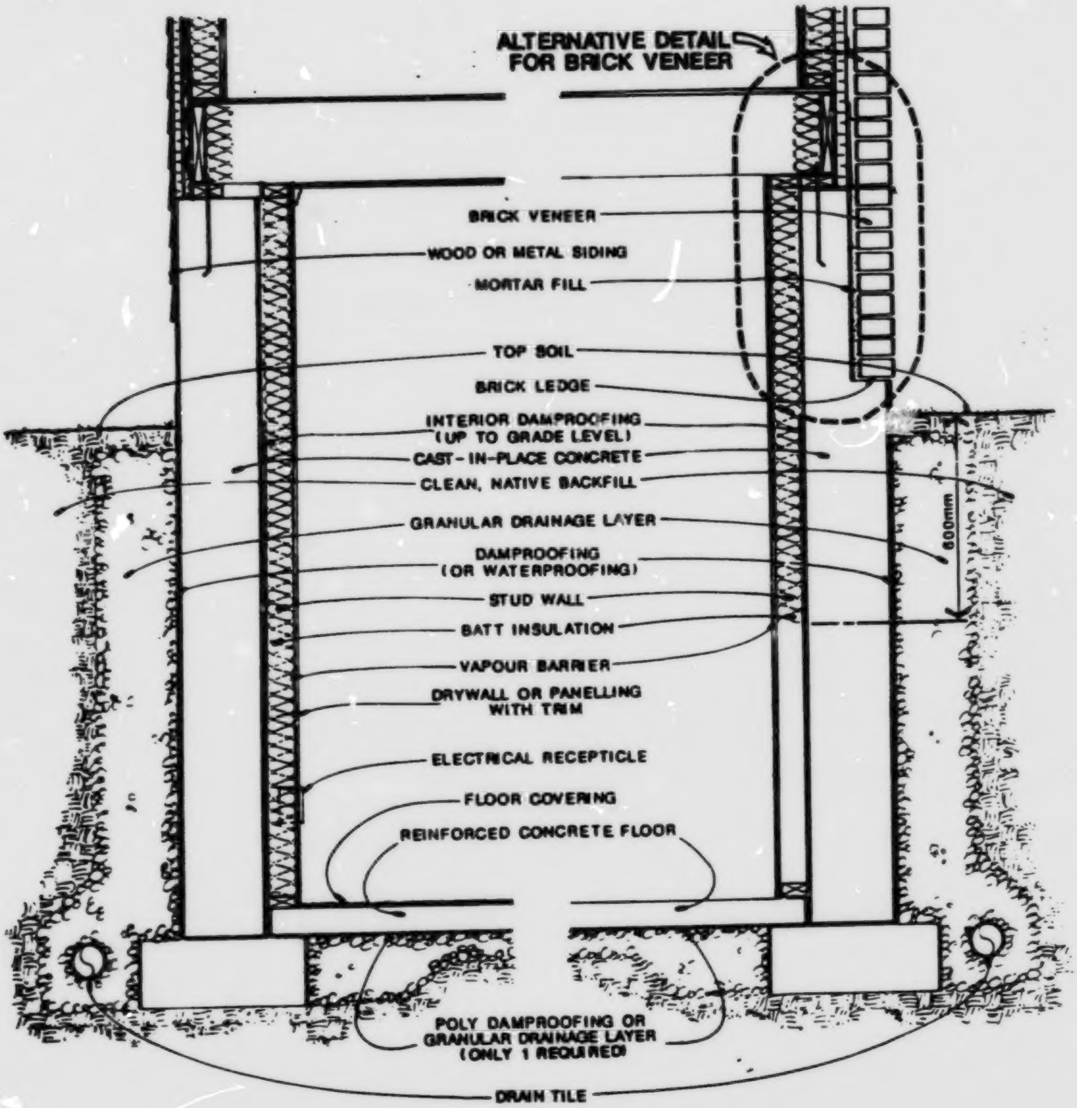
For comparison purposes, it would be desirable to define a perfect or "ideal" basement against which any advance in basement technology could be evaluated. However, it is inconceivable that such an ideal basement system could ever be found to satisfy the ever changing functional, engineering, builder and marketing issues that dictate the choice of a particular basement for a particular house. An ideal basement system for tract housing in Southwestern Ontario is unlikely to be ideal for a custom–built house in a remote area of Canada.

Lacking an ideal basement against which to compare Vanguard basement systems, this study has focused its comparisons on a Benchmark basement which consists of a site–cast concrete wall and floor structure, with an abutting insulated interior stud wall to which traditional wall finishes are applied. All of the elements of the Benchmark basement currently required by Code, that collectively comprise the system (including vapour barriers, dampproofing, etc.) are illustrated in Figure 3.4.1.

This specific system was selected as the Benchmark because it is most typical of current building practice for liveable basements. It is significant to note that basement walls of the Benchmark system consist of 8 layered elements as shown in Figure 3.4.2.

The external drainage layer that has been included with the Benchmark system, is not currently required by Code. However, it is a desirable feature for the long–term satisfactory performance of liveable basements. Some form of drainage layer has likewise been included with each of the Vanguard systems that are reviewed in Section 3.7 of this report.

Recent experience suggests that the Benchmark basement system, when designed and constructed with diligent care, can perform reasonably well. However, supplementary methods may be required to isolate such Benchmark basement systems from soil–gases (in regions of Canada where this may prove to be necessary). In addition, it has been found that trapped construction water from the concrete in the Benchmark basement (not to mention later condensation or soil moisture) may create an undesirable micro–climate within the walls for fungal growth, wood rot and the deterioration of internal basement finishes. Further research would be desirable to establish the nature and extent of such problems.


ALTERNATIVE DETAIL FOR BRICK VENEER
BRICK VENEER
WOOD OR METAL SIDING
MORTAR FILL
TOP SOIL
BRICK LEDGE
INTERIOR DAMPROOFING (UP TO GRADE LEVEL)
CAST-IN-PLACE CONCRETE
CLEAN, NATIVE BACKFILL
GRANULAR DRAINAGE LAYER
DAMPROOFING (OR WATERPROOFING)
STUD WALL
BATT INSULATION
VAPOUR BARRIER
DRYWALL OR PANELLING WITH TRIM
ELECTRICAL RECEPTICLE
FLOOR COVERING
REINFORCED CONCRETE FLOOR
POLY DAMPROOFING OR GRANULAR DRAINAGE LAYER (ONLY 1 REQUIRED)
DRAIN TILE
600mm

Living Space **Utility Space**

FIGURE 3.4.1

Benchmark Basement

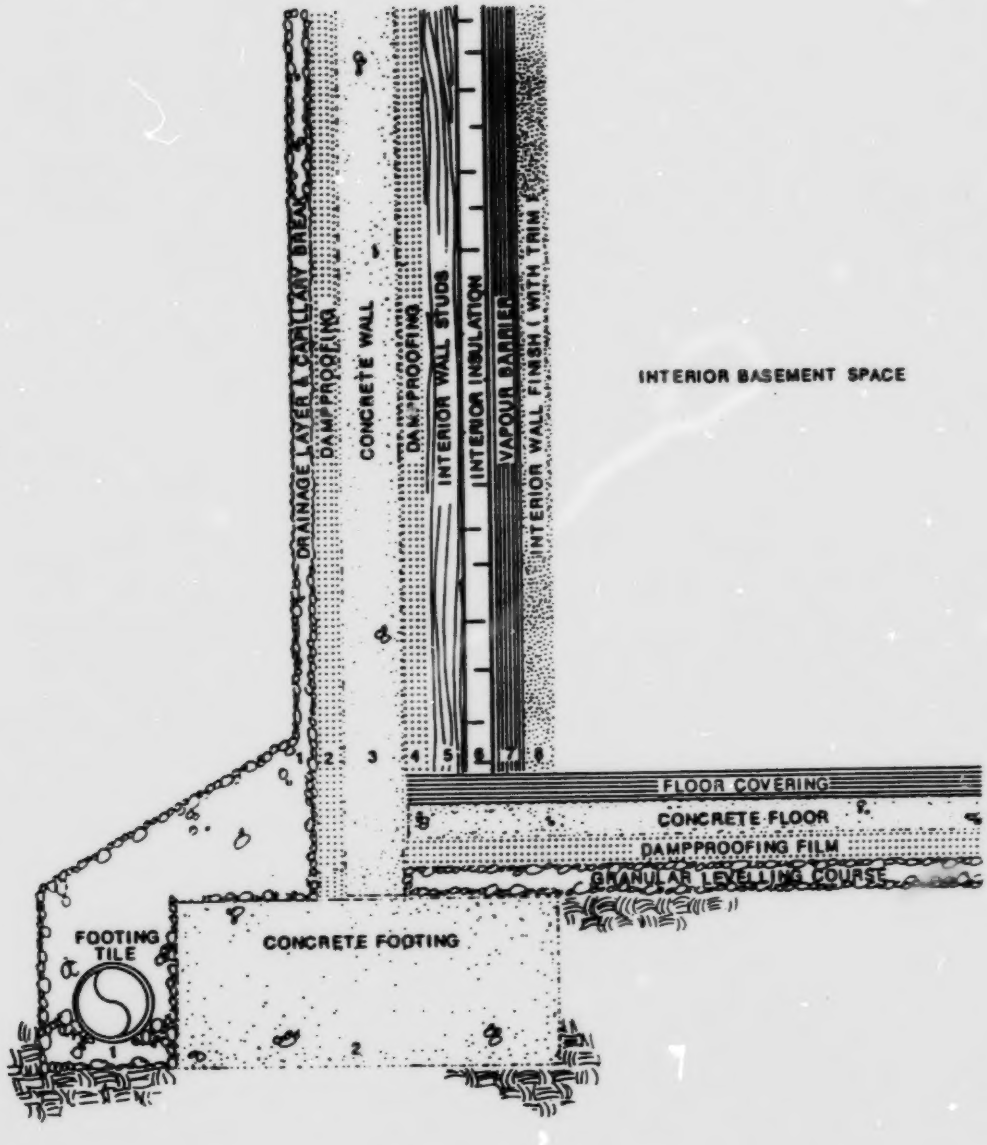

DRAINAGE LAYER & CAPILLARY BREAK
DAMPPROOFING
CONCRETE WALL
DAMPPROOFING
INTERIOR WALL STUDS
INTERIOR INSULATION
VAPOUR BARRIER
INTERIOR WALL FINISH (WITH TRIM)
INTERIOR BASEMENT SPACE
1
2
3
4
5
6
7
8
FLOOR COVERING
CONCRETE FLOOR
DAMPPROOFING FILM
GRANULAR LEVELLING COURSE
FOOTING TILE
CONCRETE FOOTING
1
2

FIGURE 3.4.2

Layered Elements of the Benchmark Basement

It is also noteworthy that the layered wall elements of the Benchmark basement system necessitate an extraordinary number of man–trips around the basement walls by various trades. As illustrated in Table 3.4.1, as many as 50 such man–trips may be required to construct the finished walls at the Benchmark basement. This reflects not only on the cost of the Benchmark system but also attests to the many opportunities for defective workmanship that arise during its construction by various trades.

The general ability of the Benchmark basement to meet the technical criteria that are fundamental to advances in basement technology are summarized in Table 3.4.2. In this tabulation, the TECHNICAL STATUS, FIRST COST, AND ON–GOING COST ratings refer only to the particular technical consideration or function. No single characterization sums up the system's status as a whole. Since each layer or element of the Benchmark basement serves more than one function, there is some unavoidable repetition in the assignment of a plus or minus in the tabulations.

3.5 INNOVATIVE TECHNOLOGIES

As previously mentioned, CMHC convened a two day symposium at the commencement of this study that was attended by building researchers; representatives of the cement, wood, steel and plastics industries; the Canadian Home Builders Association; and others knowledgeable in various aspects of basement technology.

In addition to providing direction for this study, the purpose of this seminar was to review innovative materials, methods and systems that offer potential for advancing basement technology. As a follow–up to this seminar, the study team also undertook to selectively review technical and trade literature, to attend trade exhibitions and to interview others involved with innovative housing technology.

The results of this technology search disclosed that while considerable research activity is being directed at improving the performance of individual elements of traditional basement systems, much less is being done to research, develop and market improved basement "systems" as a whole. In this respect, current innovations in basement technology appear to be more on an evolutionary than revolutionary path. Two noteable exceptions to this predominant trend are the preserved wood foundation (PWF) system and the Dofasco prefabricated steel basement system. However, neither of these systems can be classified as being new since they were first introduced some 20 years ago. Furthermore, since preserved wood foundations now account for approximately 7 percent of the total residential basement market, this system should likely be more properly classified as accepted rather than an emerging technology.

The current focus of the housing industry to improve basement materials, rather than basement systems, is likely due in part to the nature of residential standards and building codes. While these codes and standards do not prohibit the use of non–traditional basement systems, they cannot and certainly do not encourage the development and use of non–traditional systems. Codes and Standards by their very nature must be reactive and not proactive.

Table 3.4.1
The Basement Wall Parade
Construction Man–Trips Around Benchmark Basement

1. Excavate
2. Layout Footings
3. Form Outside of Footings
4. Form Inside of Footings
5. Place and Screed Concrete for Footings
6. Strip Outside of Footings
7. Strip Inside of Footings
8. Place Gravel Levelling Course Around Footings
9. Erect Outside Wall Forms
10. Install Wall Reinforcing (if required)
11. Install Wall Ties
12. Erect Inside Wall Forms
13. Install Still Plate Anchor Bolts
14. Install Window Bucks and Ledge Forms
15. Place Concrete in Wall Forms
16. Strip Inside Wall Forms
17. Strip Outside Wall Forms
18. Strip Window Bucks and Ledge Forms
19. Break–off Inside Wall Ties
20. Break–off Outside Wall Ties
21. Parge Inside Wall Tie Holes
22. Parge Outside Wall Tie Holes
23. Parge Outside Wall, Above Grade
24. Apply First Coat Dampproofing
25. Install Through Wall Pipes, Conduits
26. Apply Second Coat Dampproofing
27. Install Footing Tiles
28. Install Gravel Over Footing Tiles
29. Install and Anchor Sill Plate
30. Anchor First Floor Framing to Sill Plate
31. Install Brick Veneer, To Top of Concrete Wall
32. Backfill Walls
33. Install Dampproofing On Inside of Walls
34. Frame Stud Walls Inside Concrete Walls
35. Install Windows
36. Install Electrical Wiring in Stud Walls
37. Install Insulation in Stud Walls
38. Install Vapour Barrier on Stud Walls
39. Install Gypsum Wall Boards
40. Tape Gypsum Wall Board Joints
41. Rough Sand Wall Board Joints
42. Apply Final Joint Filler
43. Finish Sand Joints
44. Install Wood Trim
45. Paint Walls First Coat
46. Paint Walls Second Coat
47. Paint Trim First Coat
48. Paint Trim Second Coat
49. Fine Grade Backfill with Topsoil
50. Call–backs to Remedy Defects

Table 3.4.2

Benchmark Basement Evaluation

TECHNICAL CONSIDERATIONS	TECHNICAL STATUS	ECONOMIC STATUS	
		FIRST COST	ON-GOING COST
PROVIDING BASIC STRUCTURE	good	good	good
CONTROLLING EXTERIOR LIQUID WATER			
-ABOVE GRADE	good to fair	good	good
-BELOW GRADE	good to poor	good	good to poor
CONTROLLING CONSTRUCTION MOISTURE	fair to poor**	poor if int. finishing is delayed	fair to poor** if interior finishing is not delayed
CONTROLLING SOIL WATER VAPOUR			
-BY BARRIER	good to poor	good	fair
-BY AIRWAY	fair to poor	good	fair to poor
CONTROLLING SOIL GASES			
-BY BARRIER	good to poor	good	good to poor
-BY AIRWAY (See Part B)	fair to poor	good	fair to poor
CONTROLLING HEAT FLOW	good	good	good to poor
AVOIDING EXCESS CONDENSATION			
-STRUCTURE WARM	no - poor**	NA	NA
-INTERIOR VAPOUR BARRIER	good to fair	good	fair to poor**
-AVOIDING ENTRAPMENT	fair to poor**	good	fair to poor**
WITHSTANDING ABUSE (SURFACE INTEGRITY) - EXTERIOR (ABOVE GRADE) - INTERIOR FINISH	good	good	good to fair**

As the function of basements broadened, as new problems surfaced; and as non–traditional systems proved worthy of acceptance, each in turn has triggered additional code and standards provisions. To some extent, this process has resulted in the overlaying of code provisions that to some extent, mirror the layered elements of traditional basement systems themselves.

The length of time that was required to codify preserved wood foundations attests to the difficulties of gaining code acceptance of non–traditional basement systems. Moreover, code acceptance of preserved wood foundations did not come without penalties. The design requirements for PWF (i.e. the earth pressures they must be designed to resist) exceed those required of block masonry foundation walls (which were grandfathered into the first edition of the National Building Code) and PWF must be designed and inspected by a Professional Engineer or Architect in most jurisdictions of Canada, whereas concrete and block masonry foundations do not. This double standard has penalized PWF systems to some extent.

In summary, the technology search undertaken as part of this study has failed to locate any emerging basement systems that are likely to revolutionize basement construction in Canada in the forseeable future.

3.6 RATIONALIZING THE ELEMENTS OF THE BASEMENT SYSTEM

While the concrete, wood, steel and plastics industries in Canada have focused considerable research effort on improving individual elements of the total basement system (e.g. structural elements, insulation, dampproofing, etc.) it has been left largely to building scientists and engineers to develop integrated systems that optimize the performance and minimize the cost of liveable basements. Yet, such rationalizations have largely been ignored by the building industry. This reluctance to implement integrations and rationalizations of the elements of the basement system may be blamed in part on the inability of the research community to promote such concepts to the industry effectively. One notable exception to this phenomenon is the wood industry which has effectively researched, developed and promoted preserved wood foundations as a total system.

In the opinion of the authors, a concensus rationalization of the traditional, layered elements of the basement system offers the greatest opportunity for manifestly improving the performance and reducing the cost of liveable basements in Canada. The function of each layered element must be refined, costly redundancies of material and labour should be eliminated, the location of the elements within the system should be optimized and the performance of the elements should be matched to their required function.

An effective rationalization of the traditional layered elements of a liveable basement system is illustrated in Figure 3.6.1. Through the judicious placement of the elements within the system, the number of elements can be reduced, their function can be optimized and the performance of the system as a whole can be improved. The key features of this rationalized system are listed below:

1. An external composite insulation/capillary break/drainage layer.

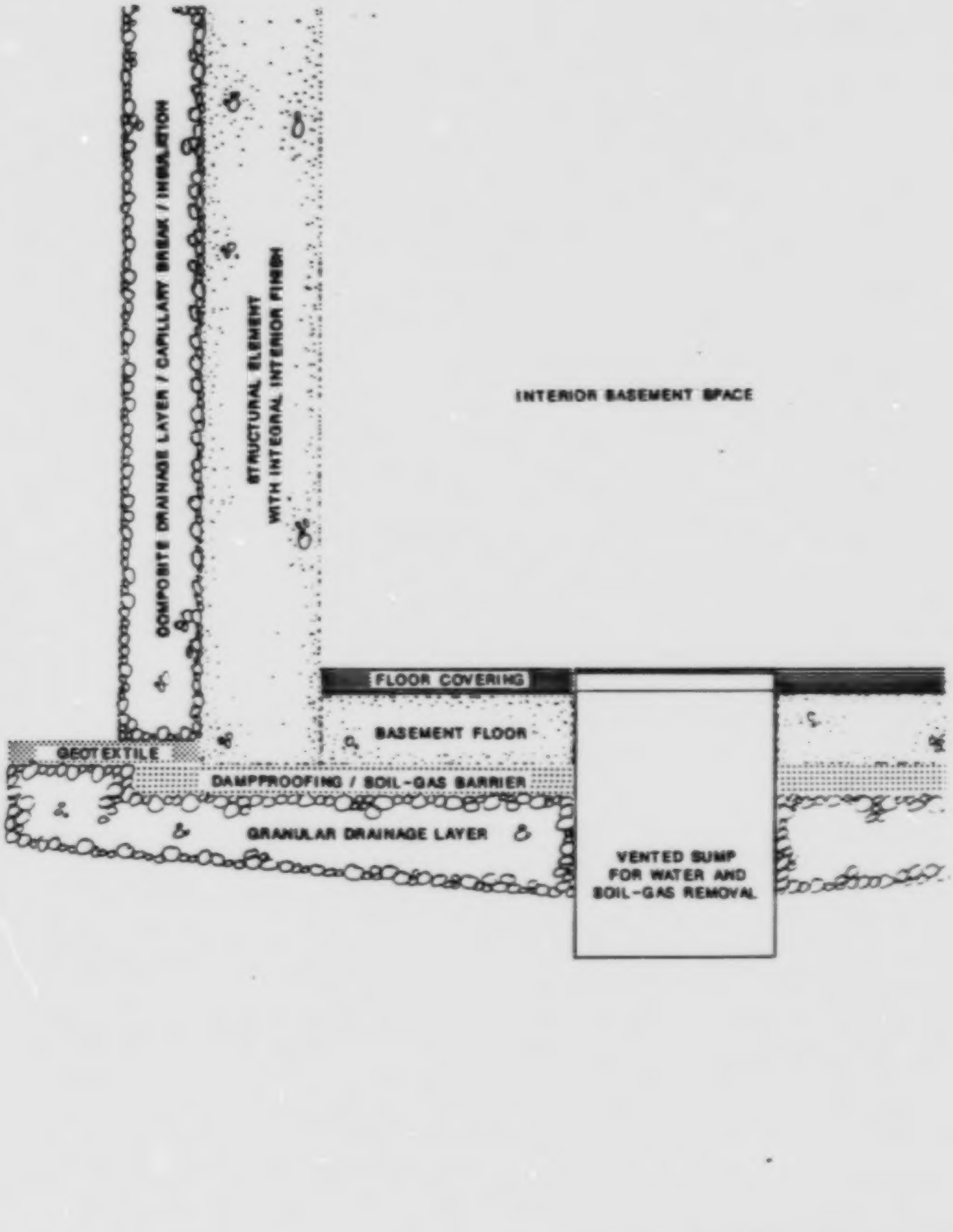

COMPOSITE DRAINAGE LAYER / CAPILLARY BREAK / INSULATION
STRUCTURAL ELEMENT
WITH INTEGRAL INTERIOR FINISH
INTERIOR BASEMENT SPACE
FLOOR COVERING
BASEMENT FLOOR
GEOTEXTILE
DAMPPROOFING / SOIL-GAS BARRIER
GRANULAR DRAINAGE LAYER
VENTED SUMP
FOR WATER AND
SOIL-GAS REMOVAL

FIGURE 3.6.1

Rationalized Basement Elements

2. A continuous, subfloor granular drainage layer that will drain liquid water and soil–gases to an enclosed, interior sump.

3. An exposed architectural wall finish on the inside of the structural wall element.

A comparison of Figure 3.4.2 and 3.6.1 illustrates that the 8 layered wall elements of the Benchmark basement can be effectively reduced to two layered elements in a properly rationalized basement system. In addition to offering significant potential for cost savings, this rationalization of the basic elements of the Benchmark basement system also offers the following performance enhancements over the Benchmark basement:

a) External, Composite Insulation/Drainage Layer

1. The use of external insulation will mitigate temperature fluctuations in the structural wall element and keep its temperature above the dew point. This will reduce thermal stresses in the foundation walls and eliminate the need for the dampproofing and vapour barrier elements required in the Benchmark basement. It will also eliminate convection loops that can permit the escape of heat through the footings and floor of internally insulated block masonry walls.

2. An external drainage layer will help isolate the structural wall element from external water and thereby eliminate hydrostatic pressure on the foundation walls and help to keep them dry.

3. The elimination of the interior dampproofing and vapour barrier required in the finished Benchmark basement will permit construction water within concrete and block masonry walls to evaporate into the basement space, thereby avoiding the entrapment of construction water behind finished wall surfaces and store needed moisture to help maintain reasonable humidity levels in houses during the winter for the first year or two.

4. By integrating the structural wall and floor elements with the interior basement space, they can be used for thermal and moisture storage for the benefit of the entire house.

5. The external drainage layer can also be used to vent soil–gases away from the perimeter of the basement, in regions of Canada where this may prove to be required.

6. The external wall insulation can also be extended horizontally outward above the footing, to raise the frost depth and facilitate the use of shallow basements and partial basements in colder regions of Canada.

b) Continuous Granular Drainage Layer

1. A continuous, granular drainage layer below the basement floor, sloped to an internal enclosed sump, can be used to control external water at least, as effectively as traditional footing tiles.

2. The granular drainage layer is also a porous media that can serve to collect subfloor soil–gases for venting through an externally vented, air–tight sump.

3. In normal average soils, the granular drainage layer should eliminate the need for a conventional concrete footing for the foundation walls.

4. The granular subfloor drainage layer will also serve as a levelling course for the basement floor slab (or a mud–free ground cover for a suspended basement floor system).

c) Integral Architectural Finish

1. Since the use of external insulation eliminates the need for an internal vapour barrier or dampproofing for a liveable basement, the structural wall elements can be provided with an integral, architectural finish to eliminate the need for a secondary finish. This should speed the construction and reduce the cost of producing liveable basement space with an acceptable wall finish.

The key features of the rationalized basement system described above are neither novel nor untested. External, insulation/drainage layers are commonly used in Scandinavian basements. Basements with exterior, insulation–drainage layer elements have also been built and tested in North America. The use of a continuous subfloor granular drainage layer is a common feature of PWF basements that have been built across Canada. The use of a granular drainage layer in lieu of footing tiles is also permitted by Code. Concrete, block masonry and wood surfaces can all be readily produced with architectural finishes that are acceptable for liveable basements.

Materials that meet the functional requirements for the rationalized basement system illustrated in Figure 3.6.1 are commercially available in Canada. Rigid fibreglass insulation and geocomposites are currently being produced and marketed for external isulation–drainage layers by competing industries. Likewise, all traditional structural materials currently being used for basements can readily be used for the structural elements of the rationalized basement system.

3.7 VANGUARD BASEMENT SYSTEMS

As discussed in Section 3.6, while a number of building scientists have advocated the use of non–traditional basement systems, the building industry has been slow to implement such changes.

Considerable research effort is being expended by the concrete, wood, steel and plastic industries, to develop improved materials that will enhance the performance and reduce the cost of individual elements of traditional basement systems. Yet, without a rationalized framework, no milestone advances in basements are likely to occur.

As part of this study, an attempt was made to synthesize vanguard materials into rationalized basement systems that although unproven hold promise of significantly improving the performance and reducing the cost of traditional basement systems. Each of these synthesized vanguard systems has been compared to the Benchmark system and for simplicity the advantages and disadvantages of each are presented in tabular form.

Since the structural elements of the Vanguard systems presented in this report are the key elements of the basement system, each of the Vanguard systems discussed in this report has been categorized into Block Systems; Precast Concrete Systems; Site Cast Concrete Systems; Preserved Wood Systems and Steel Systems. Other untraditional structural materials and hybrids (e.g. fibre reinforced plastics) would work equally well with these vanguard systems.

3.7.1 Block Systems

Two systems utilizing block elements have been identified as warranting detailed consideration in this report. These elements have been synthesized with other wall elements into a rationalized basement system. The first system utilizes decorative architectural block in lieu of plain masonry block. The second entails the use of expanded polystyrene blocks (EPS) with reinforced concrete cores.

a) Decorative Architectural Block Masonry

Decorative block manufactured with a textured and/or coloured finish (e.g. split–rib, fluted, scored, etc.) is readily available in most urban areas of Canada. And although it costs approximately 50 percent more than conventional block masonry, it is easily adaptable to complex floor plan configurations and provides an adequate finish that eliminates the need for an abutting stud wall.

A synthesized Vanguard system utilizing decorative block masonry is illustrated in Figure 3.7.1. The elements of this basement system have been synthesized to include the following:

1. Architectural block masonry with grouted, reinforced cores as required by Code and/or dictated by structural requirements.
2. An external, combined insulation and drainage layer with an above–grade protective covering.
3. A sub–floor granular drainage layer with an internal, covered sump that also serve as a soil–gas ventilation system.
4. A thickened slab footing that can either be cast conventionally (prior to the floor slab) or monolythically with the floor slab (weather permitting).
5. A flush mounted electrical distribution system installed within the baseboard (or wainscot) trim.
6. A sub–floor dampproofing and soil gas barrier.

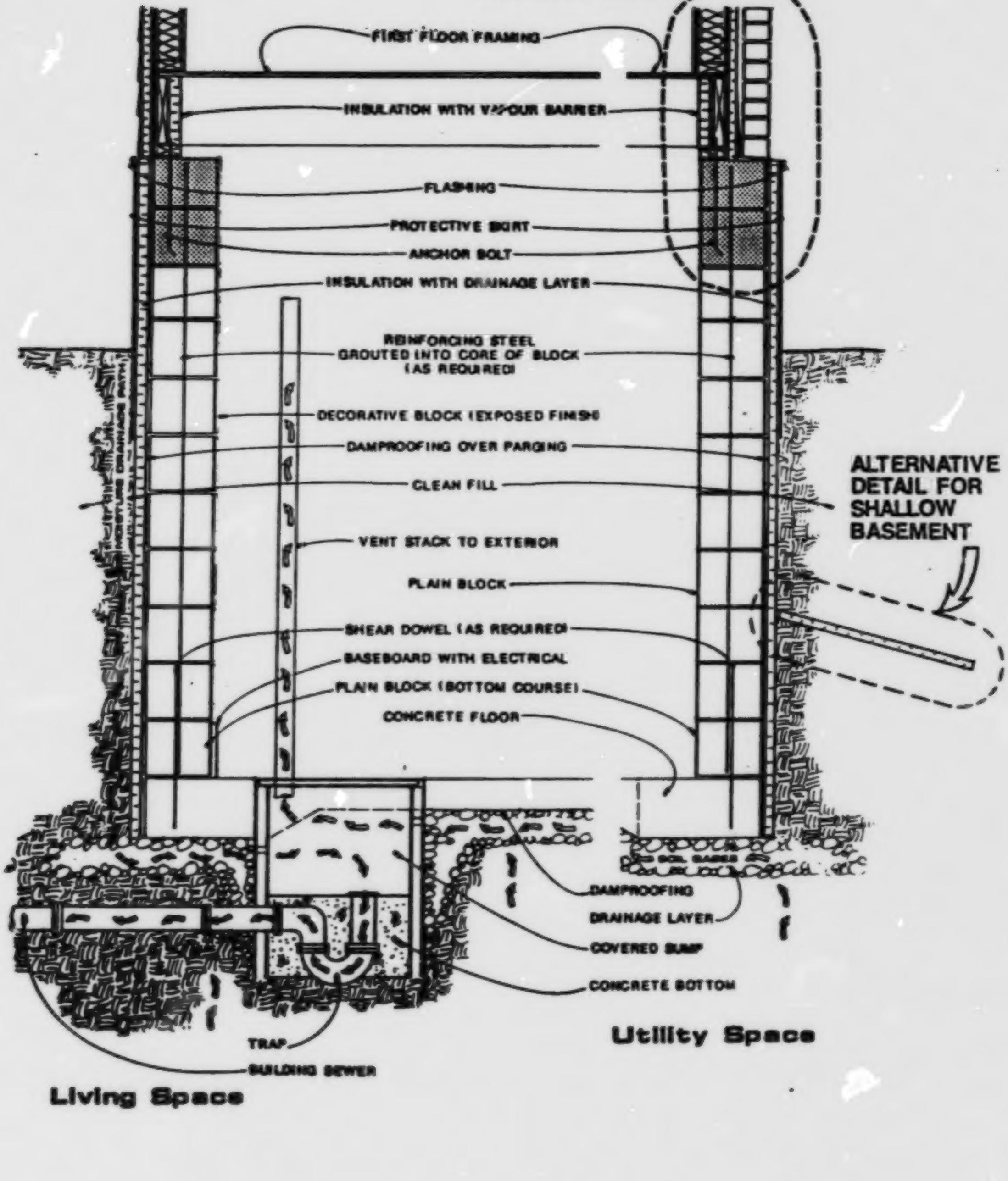

ALTERNATIVE DETAIL FOR BRICK VENEER
FIRST FLOOR FRAMING
INSULATION WITH VAPOUR BARRIER
FLASHING
PROTECTIVE SKIRT
ANCHOR BOLT
INSULATION WITH DRAINAGE LAYER
REINFORCING STEEL GROUTED INTO CORE OF BLOCK (AS REQUIRED)
DECORATIVE BLOCK (EXPOSED FINISH)
DAMPROOFING OVER PARGING
CLEAN FILL
ALTERNATIVE DETAIL FOR SHALLOW BASEMENT
VENT STACK TO EXTERIOR
PLAIN BLOCK
SHEAR DOWEL (AS REQUIRED)
BASEBOARD WITH ELECTRICAL
PLAIN BLOCK (BOTTOM COURSE)
CONCRETE FLOOR
DAMPROOFING
DRAINAGE LAYER
COVERED SUMP
CONCRETE BOTTOM
TRAP
BUILDING SEWER
Utility Space
Living Space

FIGURE 3.7.1
Architectural Block Masonry

A comparison of this Vanguard system to the Benchmark system is presented in Table 3.7.1.

This system offers the modular flexibility of conventional block masonry and can be integrated with plain masonry (within utility areas in a basement). Below grade exit doors, windows, fireplaces and other features can readily be accommodated with this system.

Although parging and dampproofing are currently mandated for block masonry foundation walls by Code, the use of a combined external insulation and drainage layer may enable a relaxation of these Code requirements for this system.

Since the interior face of the architectural block masonry is exposed to the interior of the basement, construction moisture that could diffuse through the wall in small quantities should not adversely affect the interior environment of the basement.

b) Expanded Polystyrene Block

Expanded polystyrene block (EPS) of various proprietary designs has been used in Europe for foundation walls as well as complete above–grade walls in residential and light commercial buildings for more than 25 years. The insulation thickness, overall dimensions, core configuration and wythe connections vary from manufacturer to manufacturer. Generally, these EPS blocks are larger than concrete blocks (typically 1.22 m long x 0.41 m high) and all of the edges are tongue–and–groove so that the blocks can be erected easily. The vertical cores of these EPS blocks are interconnected and are designed to be filled with steel reinforced concrete.

Although bulky to ship, EPS blocks are extremely lightweight and can be installed either on a gravel or a concrete footing. To reduce the shipping bulk of these EPS blocks, some manufacturers produce disassembled foam blocks that can be assembled on site using high strength plastic or steel ties. Mobile equipment for producing EPS block on site has also been developed.

Insulation values of RS1–3.6 and above are possible with EPS block systems. The density of the expanded polystyrene used for such blocks typically ranges from 24 kg per cubic metre to 32 kg per cubic metre. The higher density blocks are stronger and therefore better able to resist the internal fluid pressure of the concrete when it is placed in the cores. Nevertheless, the maximum height of concrete that can be placed in EPS blocks is generally limited to 1.20 m. Consequently, for full–height basements, it is generally necessary to place the block and the concrete in at least two lifts.

The interior and exterior surfaces of the EPS block can be parged and dampproofed to provide a reasonably durable dampproofed basement wall system. Such parging is usually chemically modified and applied over a fibreglass reinforcing mesh to increase the strength and the crack resistance of the parging.

Table 3.7.1
Architectural Block Masonry

TECHNICAL REQUIREMENTS	TECHNICAL STATUS	FIRST COST	ON-GOING COST
PROVIDING BASIC STRUCTURE	0,-	0	0
CONTROLLING EXTERIOR LIQUID WATER			
-ABOVE GRADE	0,-	-	0
-BELOW GRADE	+	0,-	0,+
CONTROLLING CONSTRUCTION MOISTURE	+	+	+
CONTROLLING SOIL WATER VAPOUR			
-BY BARRIER	0,-	0	0,+?
-BY AIRWAY	+	0	+?
CONTROLLING SOIL GASES			
-BY BARRIER	0,-	0	0,+?
-BY AIRWAY	++?	+	+?
CONTROLLING HEAT FLOW	0	0,-	+
AVOIDING EXCESS CONDENSATION			
-STRUCTURE WARM	++	0	++
-INTERIOR VAPOUR BARRIER	+	+	
-AVOIDING ENTRAPMENT	+	0	+
WITHSTANDING ABUSE (SURFACE INTEGRITY) - EXTERIOR (ABOVE GRADE) - INTERIOR FINISH	0,-	-?	0

NOTES:

0 = neutral, + = better, ++ = considerably better;
- = worse, -- = considerably worse, ? = questionable...
...all in comparison to benchmark system.

An illustration of the Vanguard EPS system is presented in Figure 3.7.2 and a comparison of this system to the benchmark system is presented in Table 3.7.2. While the EPS block system compares reasonably well to the Benchmark system, it does appear to have several disadvantages. The inability of EPS block to support the fluid pressure of concrete for the full height of the basement wall, the need for interior and exterior parging and the cost of expanded polystyrene itself all appear to be intrinsically costly.

While expanded polystyrene can offer good insulation capabilities indefinitely above–grade, in saturated below–grade usage, its insulation value can be greatly diminished. Moreover, the use of pargings or stuccos on expanded polystyrene does not readily offer great resistance to abuse and if damaged can allow entry by carpenter ants and other insects.

EPS block appears well suited to do–it–yourself applications since it is easier to install then conventional block masonry and eliminates the need for traditional concrete forming systems. However, the parging of the exposed surfaces necessitates specialized skills that may extend beyond the abilities of many do–it–yourselfers.

3.7.2 Modular, Precast Concrete Systems

Although modular, precast concrete systems for foundation walls (and above–grade walls) have gained widespread acceptance in Europe, they have seen only limited commercial use in Canada.

The Technical Research Committee of the Housing and Urban Development Association of Canada, (HUDAC) – now Canadian Home Builders Association – in co–operation with the Central Mortgage and Housing Corporation (now Canada Mortgage and Housing Corporation) undertook the development of a precast concrete foundation system for houses in the late 1960's. The initial development began in 1968 with the building of the HUDAC Experimental Project VI in Kitchener, Ontario. A number of other prototype precast concrete foundation systems were subsequently built and studied as part of this research project in Calgary, Hamilton and Prince George. The results of this development work were published by HUDAC in December 1973.

These early prototype precast concrete foundation systems successfully demonstrated the viability of using precast concrete panels both with and without footings and having a minimum wall thickness of only 10 cm.

A number of proprietary, precast concrete foundation wall systems are now being actively marketed in Canada and the United States. Many of these systems consist of ribbed panels with thickened edges and bolted connections. These wall panels extend the full height of the basement and are cast in widths of from 1.2 metres to 4 metres. Most are factory–cast, inside face–down, using wet–cast concrete technology. However, modular, precast concrete panels can also be extruded (using dry–cast technology that has been developed by the prestressed hollow core slab industry), site–cast (using tilt–up wall technology) dry–cast (using pressure–packer concrete pipe technology) and wet–cast in battery forms (using European technology).

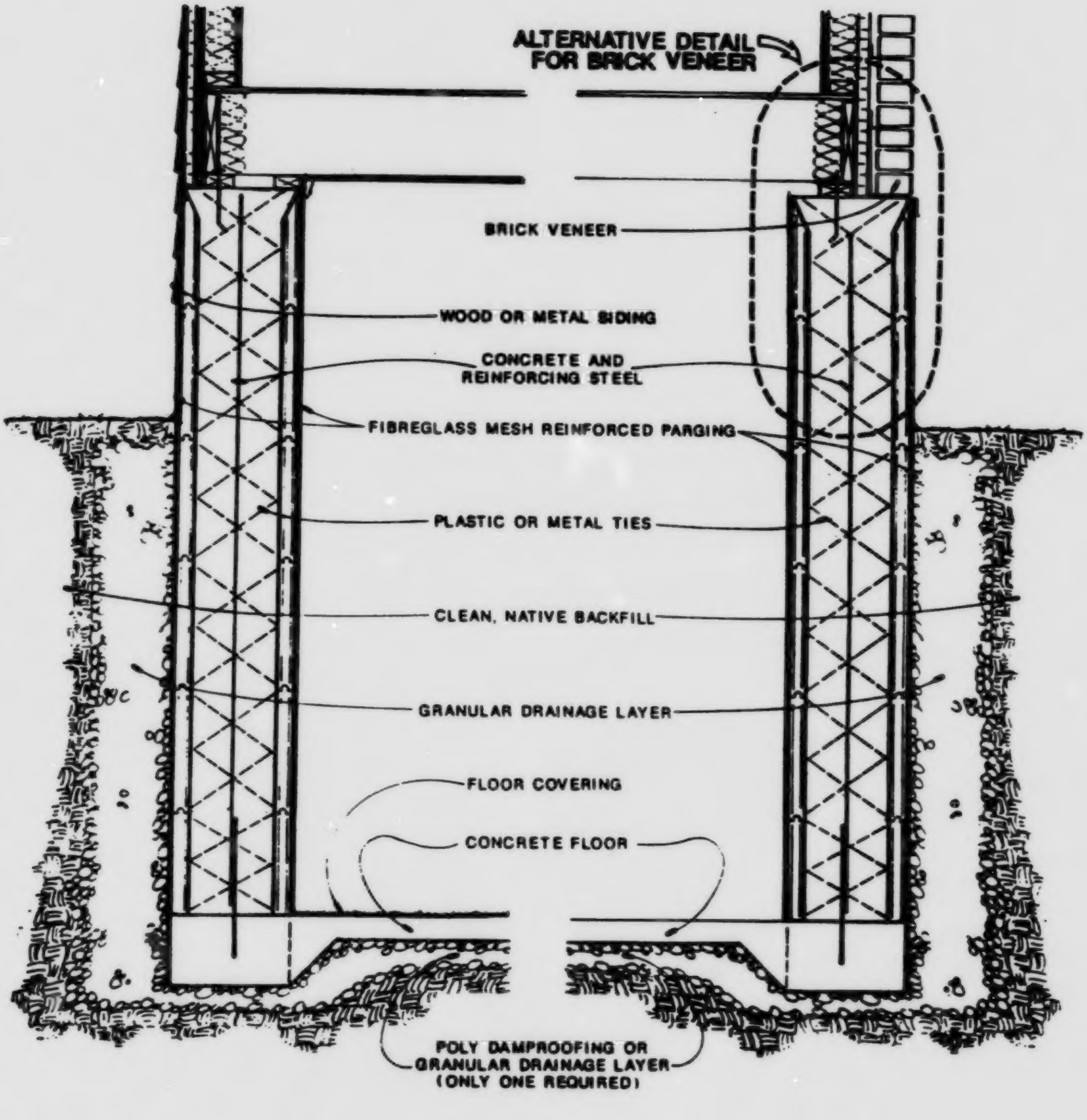

ALTERNATIVE DETAIL FOR BRICK VENEER
BRICK VENEER
WOOD OR METAL SIDING
CONCRETE AND REINFORCING STEEL
FIBREGLASS MESH REINFORCED PARGING
PLASTIC OR METAL TIES
CLEAN, NATIVE BACKFILL
GRANULAR DRAINAGE LAYER
FLOOR COVERING
CONCRETE FLOOR
POLY DAMPROOFING OR GRANULAR DRAINAGE LAYER (ONLY ONE REQUIRED)
Living Space
Utility Space

FIGURE 3.7.2

Expanded Polystyrene Block

Table 3.7.2

Expanded Polystyrene Block

TECHNICAL REQUIREMENTS	TECHNICAL STATUS	FIRST COST	ON-GOING COST
PROVIDING BASIC STRUCTURE	0,-	-	-
CONTROLLING EXTERIOR LIQUID WATER			
-ABOVE GRADE	0	0	0,-
-BELOW GRADE	0,+	0	0
CONTROLLING CONSTRUCTION MOISTURE	+	-	+?
CONTROLLING SOIL WATER VAPOUR			
-BY BARRIER	0,+	0	0?
-BY AIRWAY	0	0	0
CONTROLLING SOIL GASES			
-BY BARRIER	0,+	0	0?
-BY AIRWAY	0	0	0
CONTROLLING HEAT FLOW	+	-	0,+
AVOIDING EXCESS CONDENSATION			
-STRUCTURE WARM	0,+		
-INTERIOR VAPOUR BARRIER	0,+	0	
-AVOIDING ENTRAPMENT	0?	0	+?
WITHSTANDING ABUSE (SURFACE INTEGRITY)	-	-	-
- EXTERIOR (ABOVE GRADE)			
- INTERIOR FINISH			

NOTES:

0 = neutral, + = better, ++ = considerably better;
- = worse, -- = considerably worse, ? = questionable...
...all in comparison to benchmark system.

The advantages of using modular, precast concrete panels for basement systems seem compelling. Such panels can be precast under factory–controlled conditions using modified concrete (e.g. lightweight, water–reduced, super–plasticisized, etc.) in precision forms that can provide an excellent finish with thin, structurally efficient profiles. These panels can be erected on site in virtually any kind of weather using relatively unskilled labour.

The principal disadvantages of using modular precast concrete panels for basement systems seems to be the capital cost required to set up an efficient casting operation. The cost of transporting these panels to the job site and the mechanized equipment required to erect these panels are also disadvantages with this system.

While the joints in such modular precast panel systems must be properly engineered, experience has shown that they can be designed and constructed to be watertight. Moreover, while modular precast panel systems are not as adaptable for use with custom basements of complex configurations, they appear to be well–suited for more standardized tract housing.

Despite the design limitations of modular, precast concrete foundation wall systems, the development initiatives initiated by HUDAC and CMHC some 20 years ago have confirmed both the technical viability and potential for cost savings associated with their use, in lieu of traditional, cast–in–place concrete walls. Consequently, two Vanguard systems using precast concrete panels have been synthesized in this study and are discussed in detail in the following sections of this report.

a) Externally Insulated Precast Concrete Panels

While much effort has been focused on producing precast concrete panels that are structurally efficient (i.e. waffle slabs or ribbed slabs that minimize the quantity of concrete required) these structurally efficient panels do not facilitate the interior finishing of liveable basement space. A stud wall is generally installed along the inside of these panels to accommodate the installation of insulation and finishes in the same manner as the Benchmark system.

The Vanguard system that has been synthesized for this report, based on the use of externally insulated, precast concrete panels is illustrated in Figure 3.7.3. The elements of this system are described below:

1. An external insulation that also serves as a drainage layer.

2. A protective skirt to prevent the exterior insulation from being damaged, above–grade.

3. Precast concrete wall panels having a nominal wall thickness of from 10 cm to 15 cm, suitably reinforced and cast with an integral, exposed architectural finish. In many soil conditions, these panels can be founded directly on a granular footing.

4. A flush–mounted electrical distribution system concealed within the baseboard or wainscot trim.

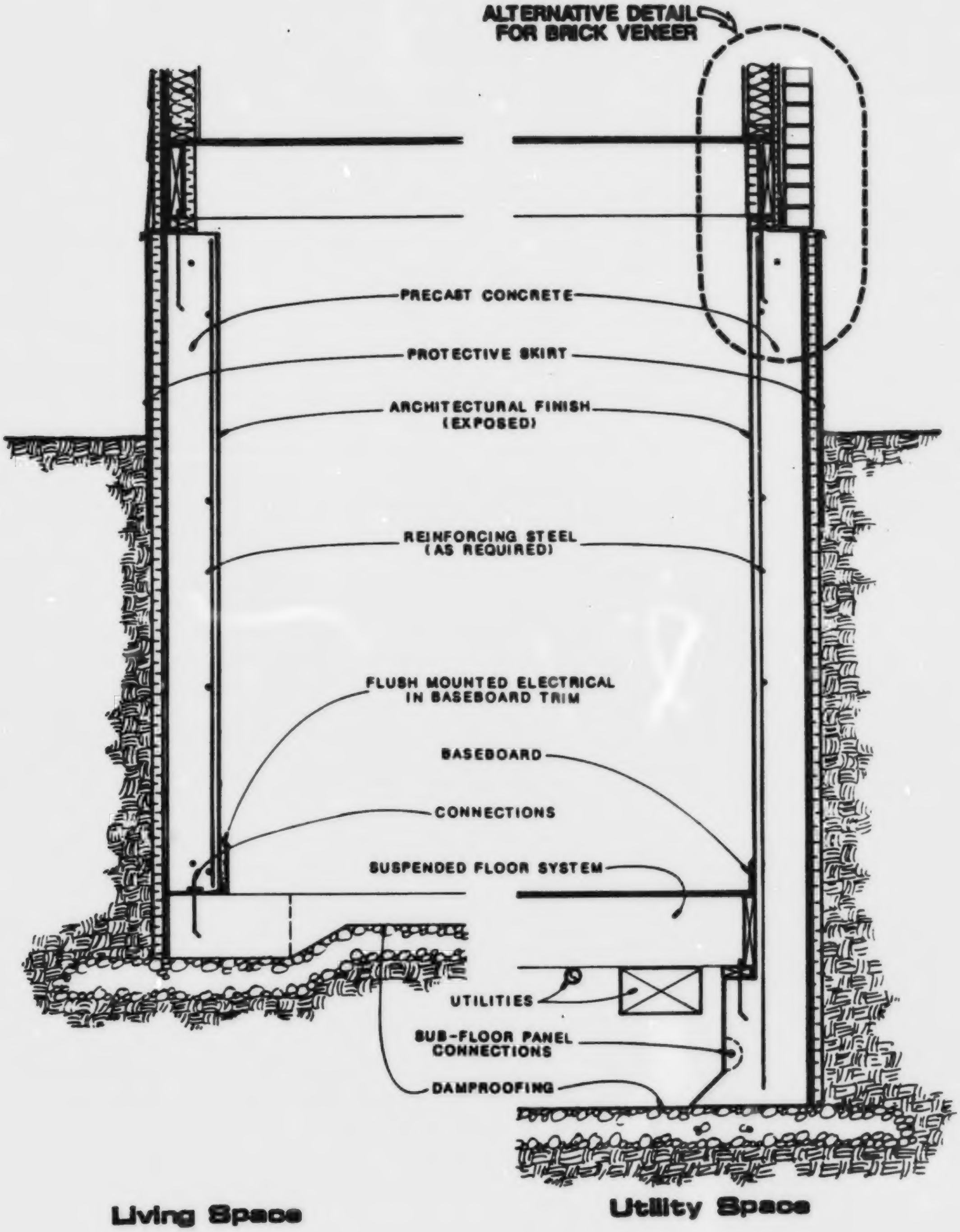

ALTERNATIVE DETAIL FOR BRICK VENEER
PRECAST CONCRETE
PROTECTIVE SKIRT
ARCHITECTURAL FINISH (EXPOSED)
REINFORCING STEEL (AS REQUIRED)
FLUSH MOUNTED ELECTRICAL IN BASEBOARD TRIM
BASEBOARD
CONNECTIONS
SUSPENDED FLOOR SYSTEM
UTILITIES
SUB-FLOOR PANEL CONNECTIONS
DAMPROOFING
Living Space
Utility Space

FIGURE 3.7.3
Externally Insulated Precast Concrete

5. A conventional concrete floor slab constructed over a granular drainage layer or alternatively, a suspended wooden floor system (over a utility chase).

6. An optional soil–gas venting system as illustrated in Figure 3.7.1.

The modular precast wall panels that form the structural elements of this system could be factory–cast using any of the methods previously described. However, whatever casting method is employed, it should be capable of providing an acceptable architectural finish on the exposed, interior side of the panels. High–quality, textured forms or reuseable form–liners have been used successfully for many years to provide architectural finishes for exposed wall surfaces.

In warm climates, precast concrete panels are often cast face–down, in casting yards that are exposed to the elements (or merely covered by a roof structure). However, this type of casting is ill–suited for the Canadian climate since it requires large factory floor areas that are expensive to build and costly to heat.

In view of the foregoing, it would likely be most cost–efficient to cast such wall panels using battery–forms similar to those that have been developed in Europe, for this purpose. A battery–forming system that would appear to be well suited for this purpose is illustrated in Figure 3.7.4.

If these precast concrete slabs are to be cast vertically in a battery–form, the height of the form should be kept to a minimum, to facilitate the placing of the concrete within the narrow widths required. It may therefore be advantageous to cast these panels on their side and to use a modular panel width of from 1.2 metres to 1.8 metres. With this spacing of vertical joints, it may also be possible to incorporate vertical drainage channels within these joints that would eliminate the need for a continuous drainage layer over the entire exterior surface of these foundation walls.

A tabulated comparison of this Vanguard system to the Benchmark basement system is presented in Table 3.7.3. The precast system compares favourably in most respects against the Benchmark system. Moreover, in urban areas, where the volume of house construction would warrant the capital outlays for such a precasting facility, it is possible that this type of system could offer cost as well as quality advantages over the Benchmark system.

b) Insulated Concrete Sandwich Panels

Because concrete is a poor insulating material, various attempts have been made to produce insulated concrete sandwich panels that can be used as total wall systems. While such panels are now being produced for above–grade use in commercial and industry buildings, because of their relatively high cost, they have not yet seen commercial application in residential construction.

Through further development and cost–reduction, sandwich panels of this type could offer advantages over traditional basement wall systems. In theory, such panels could approach the ideal for a hybrid, stand–alone system for producing economical, liveable basements. Sandwiched between external and internal layers of high quality, durable concrete, the interior insulation would be protected from abuse and the degrading effect of excess moisture, sunlight, insects, etc.

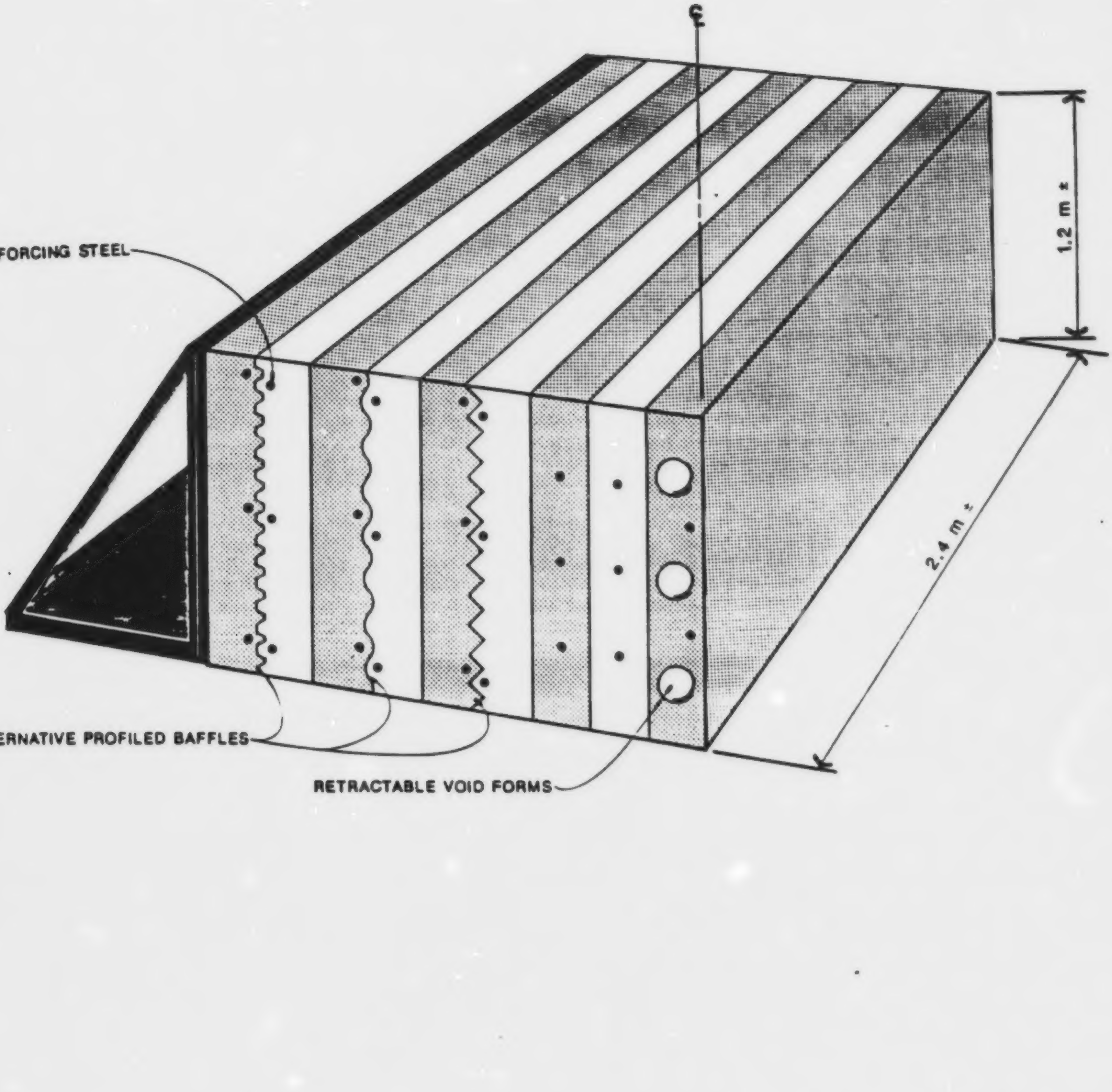

℄
REINFORCING STEEL
1.2 m ±
2.4 m ±
ALTERNATIVE PROFILED BAFFLES
RETRACTABLE VOID FORMS

FIGURE 3.7.4

Half-Section Through Battery Form

Table 3.7.3

Externally Insulated Precast Concrete

TECHNICAL REQUIREMENTS	TECHNICAL STATUS	FIRST COST	ON-GOING COST
PROVIDING BASIC STRUCTURE	0,+	0,-	0,+?
CONTROLLING EXTERIOR LIQUID WATER			
-ABOVE GRADE	0,-	-	0,-
-BELOW GRADE	+	0,-	0,+
CONTROLLING CONSTRUCTION MOISTURE	++	+	+
CONTROLLING SOIL WATER VAPOUR			
-BY BARRIER	+	0,-	0,+?
-BY AIRWAY	+	0	+?
CONTROLLING SOIL GASES			
-BY BARRIER	+	0,-	0,+
-BY AIRWAY	++?	+	+
CONTROLLING HEAT FLOW	0	0,-	0,+?
AVOIDING EXCESS CONDENSATION			
-STRUCTURE WARM	++	0	+
-INTERIOR VAPOUR BARRIER	+	+	+
-AVOIDING ENTRAPMENT	+	0	+
WITHSTANDING ABUSE (SURFACE INTEGRITY) - EXTERIOR (ABOVE GRADE) - INTERIOR FINISH	0,-	-?	0,-

NOTES:

0 = neutral, + = better, ++ = considerably better;
- = worse, -- = considerably worse, ? = questionable...
...all in comparison to benchmark system.

To date however, it has been difficult to produce such panels economically. For structural efficiency, shear connections must be provided between the inner and outer wythes of the concrete, through the insulation. Since the insulation itself is a nonstructural material, steel or concrete inner shear connections between the inner and outer concrete wythes interrupt the insulation and concrete and can result in undesirable thermal bridges through the interior insulation.

Nevertheless, with further research and development, it should be possible to produce economical concrete sandwich panels that offer an acceptable compromise between structural efficiency and insulation value. The development of rigid PVC shear connectors may solve this problem.

In many of the Vanguard systems advanced in this report, external drainage has been provided through an integral, external insulating material that also serves as a drainage layer. Since the insulation in precast sandwich panels is located within the center of the precast panel, some other means of isolating the foundation walls from the liquid water in the soil must be provided. While this could be done through the use of an external, granular drainage layer, it may also be possible to concentrate such drainage layers within the vertical jointing system of the panels, provided that these vertical joints are spaced at reasonable intervals around the perimeter of the basement. A comparison of this system to the Benchmark system is summarized in Table 3.7.4.

The advantages and disadvantages of this system generally mirror those of the externally insulated precast concrete panel system. In the short term, the relatively high cost of producing such panels may prevent their introduction into basement wall systems. However, the continuing research and development impetus of the industry that produces such panels for commercial above–grade use, may well result in technological advancements that will reduce their cost and make them viable for use in advanced residential basement systems.

3.7.3 Site–Cast Concrete Systems

As set out in Part B of this report, cast–in–place concrete is the most commonly used structural material for basements in Canada today. Wall thicknesses of from 15 cm to 30 cm for non–engineered foundation walls are permitted by Code for foundation walls that support varying heights of backfill. While some Provincial jurisdictions require the use of reinforcing steel in such foundation walls, others do not.

Proprietary, lightweight plywood and metal forms are now being used extensively in many urban centres across Canada. While these forming systems differ to some degree, virtually all have been designed to be lightweight so that they can be handled by workmen, without the use of hoisting equipment. They also require the extensive use of form–ties that are not inexpensive and are often problematic. Spaced on a rigid pattern of between 60 cm and 100 cm, they blemish the concrete surfaces and can provide pathways for water to pentrate the wall structure.

A complete set of reuseable, modular forms currently range in price from approximately $10,000 (for a plywood forming system) to over $75,000 (for a premier aluminum forming system). Moreover, to maximize the productive use of these forming systems, many Contractors are now using trucks with boom–hoist attachments to reduce their labour costs and accelerate the turn–around time for these forms.

Table 3.7.4

Insulated Precast Sandwich Panel

TECHNICAL REQUIREMENTS	TECHNICAL STATUS	FIRST COST	ON-GOING COST
PROVIDING BASIC STRUCTURE	0	0,-	0?
CONTROLLING EXTERIOR LIQUID WATER			
-ABOVE GRADE	0	0,-?	0,+
-BELOW GRADE	+	0,-	+
CONTROLLING CONSTRUCTION MOISTURE	++	0	+
CONTROLLING SOIL WATER VAPOUR			
-BY BARRIER	+	0	+
-BY AIRWAY	+	+	+?
CONTROLLING SOIL GASES			
-BY BARRIER	+	0	+
-BY AIRWAY	+	+	+?
CONTROLLING HEAT FLOW	0	-	+
AVOIDING EXCESS CONDENSATION			
-STRUCTURE WARM	++	0	++
-INTERIOR VAPOUR BARRIER	0	+	+
-AVOIDING ENTRAPMENT	+	0	+
WITHSTANDING ABUSE (SURFACE INTEGRITY) - EXTERIOR (ABOVE GRADE) - INTERIOR FINISH	+	+	+

NOTES:

0 = neutral, + = better, ++ = considerably better;
- = worse, -- = considerably worse, ? = questionable...
...all in comparison to benchmark system.

The advent of such boom trucks on residential construction sites may well herald the introduction of heavier, ganged forms that can be installed more quickly and that will require fewer (if any) form ties.

As part of this study, one such tie–less forming system has been synthesized into a Vanguard basement wall system. A conceptual design for this tie–less forming system is illustrated in Figure 3.7.5.

To facilitate the use of heavier residential wall forming systems, it may prove desirable to provide access for a boom truck into the excavated basement (possibly down a ramp through an attached garage). Centrally positioned, the boom truck could then install and remove the basement wall forms in the most efficient and safest manner. Following the stripping of the forms, the same boom truck could then also be used to facilitate the placement of the basement floor or the first floor framing.

The tie–less forming system illustrated in Figure 3.7.5 could be utilized in the following manner:

1. The bottom section of the wall forms (the footing forms) would be installed around the perimeter of the house, complete with removable spreader ties and the concrete would be placed for the footings.

2. The outside wall form panels would then be dropped onto pins in the outside footing form, commencing at the corners and leaving gaps for the required filler forms. To avoid the need for cleaning and oiling of the forms, an external insulation and drainage layer, precut to full height, could then be installed against the outside forms, to serve as a form liner.

3. Following the installation of reinforcing steel (where required) the inside wall form panels would be dropped onto the inside footing form, again, from the corners inward. The inside wall forms would be textured or prefitted with a reuseable form liner to impart an architectural finish on the inside of the concrete walls.

4. Prefabricated box–outs for windows, doors, pipes, etc., would then be lowered into the forms and mechanically attached to the top of the forms and latch–type ties would then be swung into position to lock the inner and outer wall forms together, at the top of the walls.

5. The day following the casting of the concrete in the wall forms, the forms would be stripped, cleaned and loaded back onto the boom truck for delivery to the next basement site.

The elements of the Vanguard tie–less, cast–in–place concrete basement system illustrated in Figure 3.7.5 are virtually identical to those of the externally insulated cast concrete system illustrated in Figure 3.7.3. The absence of the form ties and the use of form liners should result in an architectural finish on the inside of the basement wall that will require little additional work. The use of superplastisizers and proper vibration should minimize surface imperfections and provide finish textures that are suitable for a texture spray, sandblasted or paint finish.

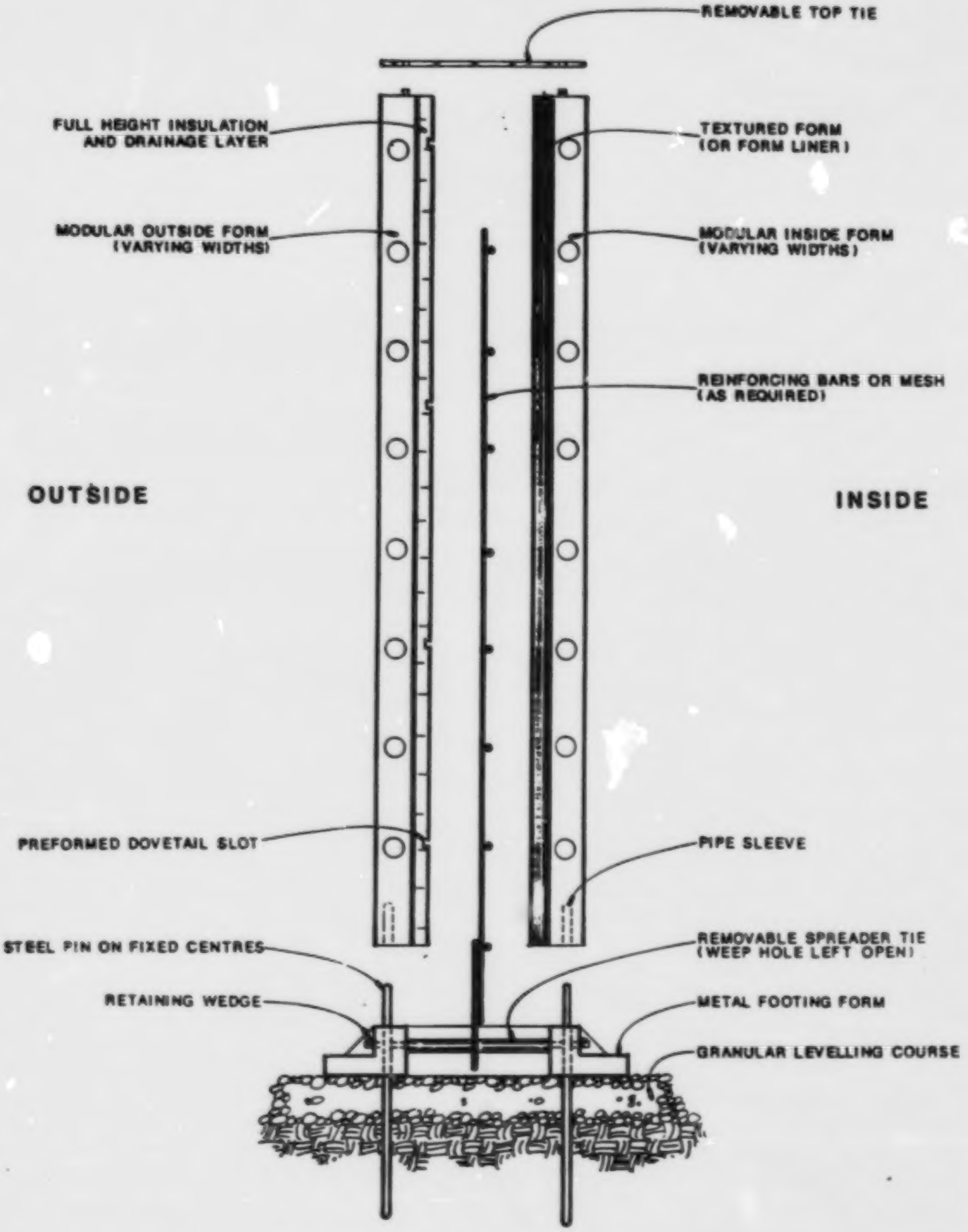

REMOVABLE TOP TIE
FULL HEIGHT INSULATION AND DRAINAGE LAYER
TEXTURED FORM (OR FORM LINER)
MODULAR OUTSIDE FORM (VARYING WIDTHS)
MODULAR INSIDE FORM (VARYING WIDTHS)
REINFORCING BARS OR MESH (AS REQUIRED)
OUTSIDE
INSIDE
PREFORMED DOVETAIL SLOT
PIPE SLEEVE
STEEL PIN ON FIXED CENTRES
REMOVABLE SPREADER TIE (WEEP HOLE LEFT OPEN)
RETAINING WEDGE
METAL FOOTING FORM
GRANULAR LEVELLING COURSE

FIGURE 3.7.5

Tie-Less Forming System

A comparison of this Vanguard system to the Benchmark system is presented in Table 3.7.5. The advantages and disadvantages of this system, compared to the Benchmark system, suggests that given adequate research and development, such systems could find application either in the near or long term.

3.7.4 Stressed–Skin PWF Systems

Several proprietary, prefabricated PWF panel systems are currently being marketed in Canada. They can be prefabricated to close tolerances using state–of– the–art equipment in a controlled factory environment. And although they may be somewhat more costly to ship than site–built materials, they can be erected quickly even under adverse weather conditions.

Current standards for preserved wood foundations in Canada do not differentiate between site built and prefabricated systems. However, under factory conditions, it should be possible to produce PWF panels using stressed–skin technology that would improve the performance and reduce the cost of such prefabricated systems.

A Vanguard system that has been synthesized based upon the use of stressed skin PWF panels is illustrated in Figure 3.7.6. This system could be used either with a treated footing plate over a granular drainage layer or with a conventional concrete footing.

A principal advantage of this PWF system is the ease with which insulation can be transitioned from outside to inside the wall without creating a significant thermal bridge. Electrical wiring can also be accommodated readily within the stud wall system.

A comparison of the stressed–skin PWF system to the Benchmark system is presented in Table 3.7.6. In addition to the advantages of the PWF system discussed above, prefabricated panels that are "factory–sealed" reduce the possibility of field error and damaging the preservative by field cutting.

3.7.5 Externally Insulated Steel Systems

The development of steel basement systems was pioneered by Dofasco Inc. in 1971. And although this development work was not targeted specifically at liveable basements, test results on full–scale, prototype steel basements have confirmed the viability of using galvanized, light–gauge, flat–rolled steel as the structural element in residential buildings.

The experimental steel basements developed by Dofasco were constructed with both exterior and interior insulation. The best results (i.e. basements with the least heat loss) were achieved through the use of full–height, exterior rigid fibreglass insulation that also served as a drainage layer. The interior of the profiled steel sheets was finished with drywall applied over horizontal wooden strapping that was screw–fastened to the steel.

A liveable basement system, based upon the Dofasco design has been synthesized into a Vanguard system and is illustrated in Figure 3.7.7. This system can be installed either on a galvanized steel footing plate over a granular drainage layer or on a conventional concrete footing. Like the PWF system, the steel system can be used either with a conventional concrete basement floor or a suspended floor system.

Table 3.7.5

Tie-Less Cast-In-Place Concrete

TECHNICAL REQUIREMENTS	TECHNICAL STATUS	FIRST COST	ON-GOING COST
PROVIDING BASIC STRUCTURE	+	0,+	+
CONTROLLING EXTERIOR LIQUID WATER			
-ABOVE GRADE	0,-	-	0,+
-BELOW GRADE	+	0,-	0,+
CONTROLLING CONSTRUCTION MOISTURE	+	+	+
CONTROLLING SOIL WATER VAPOUR			
-BY BARRIER	+	0	+
-BY AIRWAY	+	0	+?
CONTROLLING SOIL GASES			
-BY BARRIER	+	0	+
-BY AIRWAY	++?	+	+
CONTROLLING HEAT FLOW	0	0,-	0,+?
AVOIDING EXCESS CONDENSATION			
-STRUCTURE WARM	++	0	+
-INTERIOR VAPOUR BARRIER	+	+	+
-AVOIDING ENTRAPMENT	+	0	+
WITHSTANDING ABUSE (SURFACE INTEGRITY) - EXTERIOR (ABOVE GRADE) - INTERIOR FINISH	0,-	0,-?	0

NOTES:

0 = neutral, + = better, ++ = considerably better;
- = worse, -- = considerably worse, ? = questionable...
...all in comparison to benchmark system.

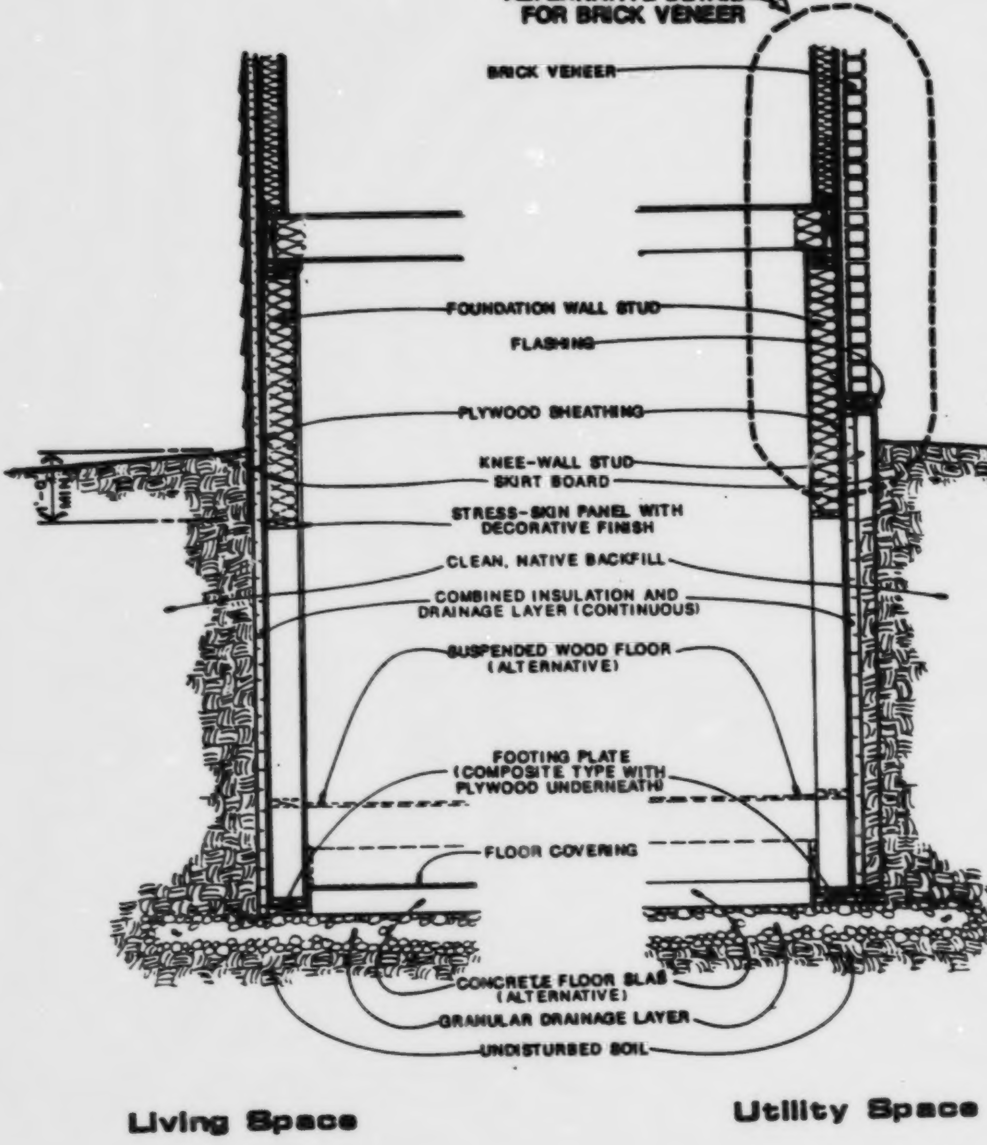

ALTERNATIVE DETAIL FOR BRICK VENEER
BRICK VENEER
FOUNDATION WALL STUD
FLASHING
PLYWOOD SHEATHING
KNEE-WALL STUD
SKIRT BOARD
STRESS-SKIN PANEL WITH DECORATIVE FINISH
1'-0" MIN
CLEAN, NATIVE BACKFILL
COMBINED INSULATION AND DRAINAGE LAYER (CONTINUOUS)
SUSPENDED WOOD FLOOR (ALTERNATIVE)
FOOTING PLATE (COMPOSITE TYPE WITH PLYWOOD UNDERNEATH)
FLOOR COVERING
CONCRETE FLOOR SLAB (ALTERNATIVE)
GRANULAR DRAINAGE LAYER
UNDISTURBED SOIL
Living Space
Utility Space

FIGURE 3.7.6
Stressed Skin PWF

Table 3.7.6
Stressed-Skin Preserved Wood

TECHNICAL REQUIREMENTS	TECHNICAL STATUS	FIRST COST	ON-GOING COST
PROVIDING BASIC STRUCTURE	0	0,-?	0,+?
CONTROLLING EXTERIOR LIQUID WATER			
-ABOVE GRADE	0	0	0
-BELOW GRADE	+	0,-?	0,+
CONTROLLING CONSTRUCTION MOISTURE	++	+	+
CONTROLLING SOIL WATER VAPOUR			
-BY BARRIER	0,+	0,+	0,+
-BY AIRWAY	+	0,+	0,+
CONTROLLING SOIL GASES			
-BY BARRIER	0,+	0,+	0,+
-BY AIRWAY	+	0,+	0,+
CONTROLLING HEAT FLOW	+	-	0,+
AVOIDING EXCESS CONDENSATION			
-STRUCTURE WARM	+	0	0,+
-INTERIOR VAPOUR BARRIER	0,+	0,+	0,+
-AVOIDING ENTRAPMENT	+	0	+
WITHSTANDING ABUSE (SURFACE INTEGRITY)	0	0	0
- EXTERIOR (ABOVE GRADE)			
- INTERIOR FINISH			

NOTES:

0 = neutral, + = better, ++ = considerably better;
- = worse, -- = considerably worse, ? = questionable...
...all in comparison to benchmark system.

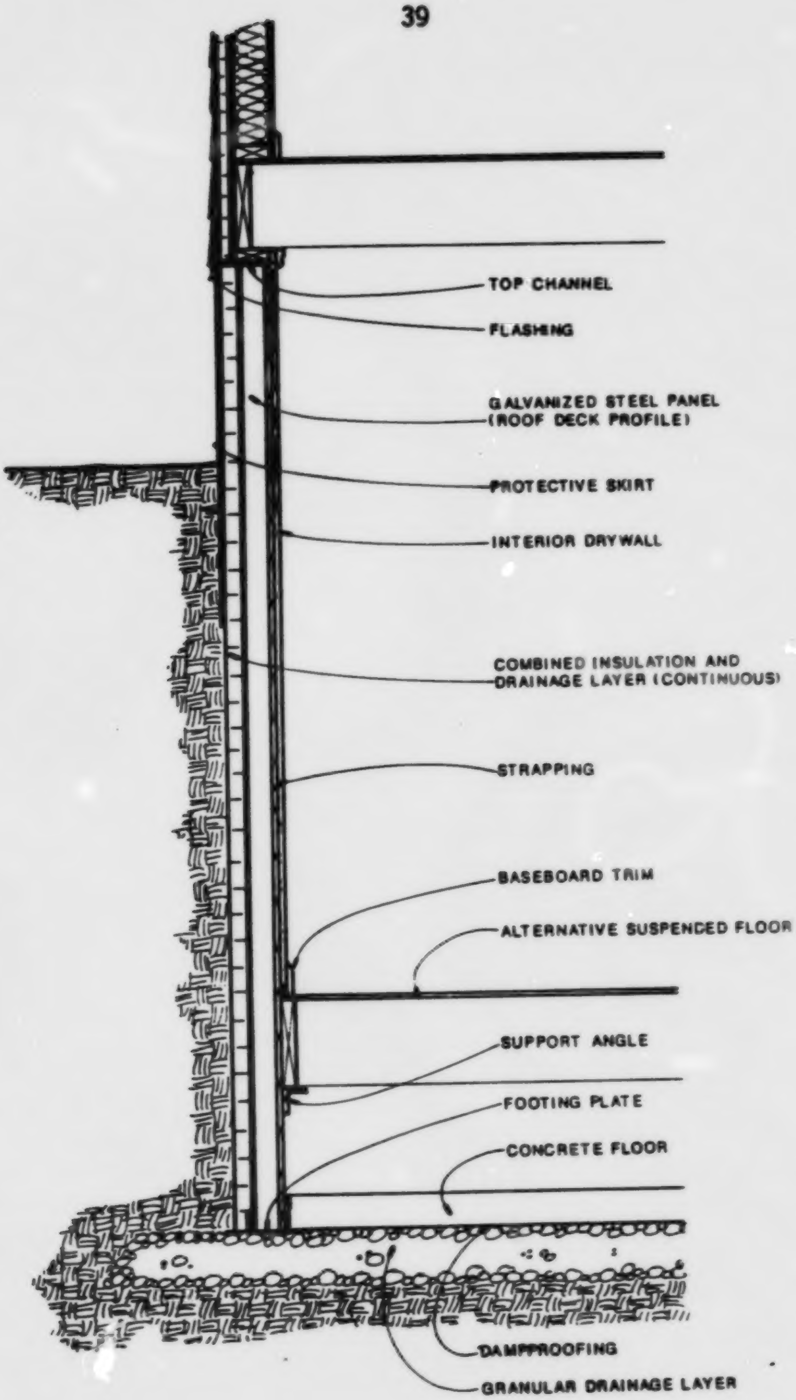

TOP CHANNEL
FLASHING
GALVANIZED STEEL PANEL (ROOF DECK PROFILE)
PROTECTIVE SKIRT
INTERIOR DRYWALL
COMBINED INSULATION AND DRAINAGE LAYER (CONTINUOUS)
STRAPPING
BASEBOARD TRIM
ALTERNATIVE SUSPENDED FLOOR
SUPPORT ANGLE
FOOTING PLATE
CONCRETE FLOOR
DAMPPROOFING
GRANULAR DRAINAGE LAYER

FIGURE 3.7.7

Prefabricated Steel

Although the earliest prototype steel basement has been in service less than 20 years, the longevity of galvanized steel in similar environments has been well established and can be increased as required through proven technologies (e.g. galvanizing, cathodic protection) to match the required design life of the house. Moreover, both the thickness of the steel and its profile can be varied to suit the anticipated loading conditions (even in expansive soils).

A tabulated comparison of the externally insulated steel system to the Benchmark system is presented in Table 3.7.7. The principle advantages of the steel system are listed below:

1. Steel contains no moisture that in itself can result in entrapped water collecting within the wall structure.
2. Galvanized, light–gauge, flat–rolled steel is readily available in Canada and can be nested for easy shipping.
3. The profiled steel panels are manufactured to exacting tolerances and can be precut or field cut, as required to suit the installation.
4. The steel panels are relatively light and can be installed entirely without the use of hoisting equipment.
5. Steel basements can be installed quickly, even in adverse weather conditions.

Although steel basements have not yet been commercially used, preliminary studies carried out by Dofasco Inc. would indicate that if produced in volume, such basements would be comparable in price to the Benchmark system.

3.8 FURTHER RESEARCH AND DEVELOPMENT

The scope of this study included identifying research needs and development opportunities that would advance basement technology. Obviously, any research and development activity focused on the basement system offers the potential for advancing basement technology and should be encouraged. However, during the course of this study, certain knowledge gaps were identified that clearly warrant research and development attention.

a) Building Science

a. Additional field studies to analyze the micro–climate within the wall finishes of internally insulated finished basements in newly constructed houses for the purpose of establishing the long–term influence of the micro–climate on the basement environment (e.g. entrapped construction water, fungal growth and deterioration of the wall elements.

b. Confirmation of the foundation soil pressures exerted on foundation walls with and without an external insulation–drainage layer.

c. Comparative studies on the effectiveness of different types of films and coatings to serve as soil–gas barriers.

TABLE 3.7.7
Externally Insulated Steel Panel

TECHNICAL REQUIREMENTS	TECHNICAL STATUS	FIRST COST	ON-GOING COST
PROVIDING BASIC STRUCTURE	0	0,-	0,-?
CONTROLLING EXTERIOR LIQUID WATER			
-ABOVE GRADE	0,-	-	0,-
-BELOW GRADE	+	0,-	0,+
CONTROLLING CONSTRUCTION MOISTURE	++	+	+
CONTROLLING SOIL WATER VAPOUR			
-BY BARRIER	+	0,-	0,+
-BY AIRWAY	+	0	+?
CONTROLLING SOIL GASES			
-BY BARRIER	+	0,-	0
-BY AIRWAY	++?	+	+
CONTROLLING HEAT FLOW	0	0,-	0,+?
AVOIDING EXCESS CONDENSATION			
-STRUCTURE WARM	++	0	+
-INTERIOR VAPOUR BARRIER	+	0	+
-AVOIDING ENTRAPMENT	+	0	+
WITHSTANDING ABUSE (SURFACE INTEGRITY) - EXTERIOR (ABOVE GRADE) - INTERIOR FINISH	-	-	0,-

NOTES:

0 = neutral, + = better, ++ = considerably better;
- = worse, -- = considerably worse, ? = questionable...
...all in comparison to banchmark system

d. Studies to confirm the soil–water and soil–gas flow rates through external insulation–drainage layers.

e. Studies to confirm convective soil–gas/air movement from subfloor granular drainage layers interconnected with an external foundation wall insulation–drainage layer.

f. Continuing studies on cost–effective methods for utilizing externally insulated basement floor and wall systems for integral thermal storage.

g. Studies to determine the need and optimum location for an air barrier between the outside environment and the drainage layer. Without such a barrier, a depressurization of the subfloor drainage layer could draw cold outside air below the basement floor in the winter.

b) Basement Systems

a. Prototype installation of basements constructed using the Vanguard systems described in this report to compare their cost, performance and marketability to the Benchmark basement.

b. Research, development and testing of the tie–less forming system concept presented in this study including the use of an external insulation/drainage layer material that can also be used as a form liner.

c. Research and development of a battery forming system for plant–cast and site–cast precast concrete wall panels suitable for use with thin, superplasticized concrete, with an integral, interior architectural finish.

d. Development and testing of stressed–skin preserved wood foundation panels complete with an integral, interior architectural finish.

e. Further research and development of the Dofasco prefabricated steel foundation wall system with an external insulation–drainage layer and an integral finish.

f. Research and development of ganged concrete forms suitable for use with a composite exterior insulation–drainage layer–form liner and an interior, reuseable form liner that can be installed and stripped by a truck mounted boom crane.

g. Further research and development into precast concrete sandwich panels with insulating shear connectors and vertical joints designed for soil–water drainage.

c) Materials

a. Further research and development of external claddings for above–grade, exterior insulation that is robust, easy to install and architecturally pleasing.

b. Development of a shelf angle system for brick veneer that will not cause significant thermal bridging and that can be utilized with externally insulated foundation walls.

c. Continued development of economical, external insulation–drainage layer materials suitable for use with externally insulated basements.

d. Development of low cost adhesives and/or fasteners to facilitate the installation of exterior insulation on foundation walls.

e. Continued research and development of soil–gas barrier films and coatings suitable for use under basement floors and on the exterior of foundation walls.

f. Further research and development of flexible joint sealants impervious to water and soil–gases.

g. Continued research and development of concrete additives and hybrid materials for crack–free basement floors.

h. The development of a composite insulation–drainage layer suitable for installation on the exterior of basement walls that can also serve as a form liner for site–cast concrete basement walls.

i. Continued research into new materials and hybrid concrete, steel and wood materials that will improve their performance and reduce their cost in basement systems.

4.0 CONCLUSIONS

In reflecting upon the complexities involved in advancing basement technology, within the changing context of functionality, produceability, reliability, affordability and marketability, it is not surprising that the housing industry in Canada is finding it difficult to achieve this goal. The building science requirements for liveable basements are myriad and ever changing. As scientists uncover new problems (e.g. soil–gases, fungal growth) solutions must found, codes revised and construction changes implemented. As new elements are added to the basement system, it becomes more difficult to see the system, for the elements.

Because of the diversities of Canada's geography, geology, climate and regions, the housing industry's quest for an "ideal basement system" is likely to remain elusive. No single technology or system is likely to satisfy all of the distinct preferences of both home buyers and home builders.

In attempting to cater to the varied interests of a broad readership, this study has had to maintain the broadest possible focus. It looks back at where basement technology has led the industry and then looks forward to advancement that hold promise for improving the quality and affordability of liveable basements in Canada.

The results of this study indicate that modest improvements to basements are indeed possible through closer adherence to existing building codes and standards, additional emphasis on quality control, more diligent inspections by code enforcement authorities and through continued improvements in the individual elements of traditional basement systems. However, these advancements are unlikely to be measured in terms of major milestones.

Major advancements in basement technology will likely only be achieved by looking beyond the individual, layered elements of traditional basements to basement systems as a whole. A number of building scientists have confirmed the viability and desirability of reconfiguring and optimizing the traditional elements of residential basements. However, these proposals have largely been ignored by the building industry; perhaps because they are unconventional or perhaps because they lack the sponsorship of broad segments of the housing research community.

The principal conclusion of this study is that a rationalization of the layered elements of traditional basement systems is the key that should unlock significant advancement in basement technology. Through such a rationalization, the multiple wall elements of the Benchmark basement can effectively be reduced from 8 layers to 2 layers. In addition, more judicious positioning of these elements within the system will manifestly improve the performance, reliability and cost of liveable basements.

A number of rationalized, vanguard systems incorporating the use of concrete, block, preserved wood and galvanized steel structural materials are presented conceptually in Section 3.7 of this report. The common features of these different vanguard systems include the following:

1. An external, composite, drainage layer/capillary break/ insulation material extending the full height of the basement walls.
2. A continuous, granular, subfloor drainage layer with an internal, covered sump, for the collection of water and soil–gases.
3. An exposed, integral architectural finish on the inside of the structural wall element of the basement.

Through focused research and concerted promotion by the major segments of the housing research community, it is felt that the advancements offered by rationalized basement systems will readily be implemented by the industry. Knowledge gaps, research needs and development opportunities that were identified as part of the study are presented in Section 3.8 of this report.

REFERENCES

During the course of this study, the study team not only drew considerable reference from their own experience but also relied upon the experience of the representatives of the housing research community and the housing industry who participated in this study. Consequently, to list all of the reference material upon which this study is based is not possible. However, a list of the reference literature from which the study team drew specific quotations and vanguard opinions is presented below:

1. "Market Research Handbook", Statistics Canada, Minister of Supply and Services Canada, November 1984.
2. "Improved Foundation Design for Low–Rise Residential Construction", McCance, William M., HUDAC Research Department Report, 1973.
3. "Design Criteria for Basement Foundation Systems in Canadian Housing", Prepared for the HUDAC Research Committee by Scanada Consultants Limited in 1974.
4. "Precast Concrete Foundation Systems for Low–Rise Housing", HUDAC Technical Research Committee, 1973.
5. "Case History of a Steel Basement System", Zakrewski, A.S., and Schurter, P.G., Presented at the Annual Conference of the American Society of Civil Engineers in 1981.
6. "New Basement Wall Designs for Below–Grade Living Space", A. Elmroth and I. Hoglund, Canada Institute for Scientific and Technical Information, 1975. (Translation from the Swedish).
7. "Glass Fiber as Insulation and Drainage Layer on Exterior of Basement Walls", S.S. Tao, M. Bomberg and J.J. Hamilton, Prepared for ASTMC–16 Thermal Insulation Conference in October 1978.
8. "Preliminary Cost Screening of Basement Foundation System Potentials", Scanada Consultants Limited, Prepared for the Housing and Urban Development Association of Canada, February 1974.
9. "External Insulation of Basement Walls – Phase II Report", HUDAC 1981, and "External Insulation of Basements", HUDAC Technical Research Committee, 1982.

APPENDIX A

SUMMARY OF PRESENTATIONS
SYMPOSIUM ON ADVANCES
IN BASEMENT TECHNOLOGY

SUMMARY OF PRESENTATIONS
SYMPOSIUM ON ADVANCES IN BASEMENT TECHNOLOGY
CMHC NATIONAL OFFICE, OTTAWA
20, 21 SEPTEMBER 1988

ATTENDEES:

Peter Russell - CMHC
Gerry Allen - Canadian Portland Cement Association
Al Houston - CMHC
Bob Platts - Scanada Consultants Ltd.
Os Hansen - Scanada Consultants Ltd.
Don Johnston - CMHC
Luc Cecire - NRC (CCMC)
Gerry Purchase - Regional Realty
Adair Chain - IRC
Gint Mitalis - NRC (IRC)
Fred Edgecombe - Society of Plastic Industries
Paul Schurter - Dofasco
Bob Sloat - Canadian Home Builders Assoc.
Peter Mazikins - Canadian Wood Council
Louis Rodriguez - CMHC
Jim Light - CMHC
David Eyre - Saskatchewan Research Council
Tony Wellman - CMHC
John Timusk - University of Toronto
Terry Robinson - CMHC
Doug Stewart - CMHC
Norm Becker - N.K. Becker & Associates Ltd.

SUMMARY OF PRESENTATIONS:

Peter Russell, CMHC

Mr. Russell opened the Symposium by introducing the attendees and briefly describing the project background for the Advances in Basement Technology Study. He explained that those in attendance had been invited as leaders in the home building industry and research community to guide the study team and provide insight into problems and solutions with residential basements.

As part of its on-going research efforts, the CMHC hopes to focus attention on methods for improving the quality and habitability of basements. The focus of this specific study was initially targetted towards the exclusion of radon and other soil-gases from basements. However, recent research in North America (particularly in the United States) has resolved what should be done to address this problem. Consequently, the CMHC decided to expand the scope of this Advances in Basement Technology Study to take a broader (proactive) look at basements, rather than focus only on methods for excluding radon from basements.

This study will address all of the major technical issues (e.g. air tightness, structural strength, durability, etc.) that must be considered collectively, to improve the performance and habitability of basements. As such, it will consider basements as a "System".

Mr. Russell explained that this study is somewhat unusual for CMHC because it is very forward looking. This study will focus on directions as to how basements will be built in the future and will identify various methods for generally improving residential basements.

Norbert K. Becker - N.K. Becker & Associates Ltd.

Dr. Becker explained that his firm was awarded the Contract for this study by CMHC, in association with Scanada Consultants Ltd., J.K. Yuill & Associates Ltd. and David Eyre of the Saskatchewan Research Council. As such, they sought the valuable input of those who had been invited to attend this Symposium by CMHC.

This study is particularly broad and will include a review of current basement design and construction practices, the technical issues that must be taken into consideration in advancing basement technology, etc. It will be targetted to the housing construction industry and to the housing research community. It will look at the status quo, identify materials and practices that can be implemented within existing codes and identify promising materials and systems that warrant further evaluation and research.

The purpose of this study is not to identify a "single best" basement system, but rather to consider alternative approaches that through technological advances promise to improve the performance and habitability of basements.

Gerry Purchase - Regional Realty

Mr. Purchase indicated that he had canvassed the opinion of several experienced House Appraisors in the Ottawa area as to the value placed on basements by home purchasers.

Generally, the value added depends upon the size of the house itself. Basements are of more value to smaller houses. Basements tend to be surplus areas in houses having floor areas in excess of 3,000 square feet. Consequently, basements under such larger houses provide little return on investment, since they are not perceived to add significantly to the value of larger houses.

Specific design features of a basement influence the market value of a house. Finished, walk-out basements are very popular with home buyers. The use of light wells in basement areas that integrate the basement with the upper levels of the house also increase the utility and therefore the value of basements.

Other Appraisors and salesmen to whom Mr. Purchase has spoken generally agree that houses without basements tend to be poor sellers. Everyone seems to want a basement (even if only for storage). Basements are more important to buyers of smaller houses and the value of such basements depends largely upon the "perception" that the buyer has of the basement.

Louis Rodriguez - CMHC

In his presentation, Mr. Rodriguez set out the architectural utilization issues pertaining to basements. Recent studies conducted by the CMHC and others have confirmed that basements offer an enormous potention when viewed in light of the life-cycle changes of a family. He described the relationship between the life events in a family and the utilization of basements. The primary developmental stages that affect this relationship are set out below:

1. Birth: Affordability is of paramount importance to most first-time home buyers. Basements offer affordable space and rentable space. By renting basement space, first-time home buyers can generate revenue to make their home purchase more affordable. With "birth", privacy also becomes important. Basements are perceived by many to be a quiet, private space in a house.

2. Pre-school to childhood: At this stage in a family development, basements offer the potential of recreational space where young children can play, make noise and indulge in activities that might not be acceptable elsewhere in the house. In cold climates, basements provide sheltered areas for children to play in the winter.

3. Childhood to Adolescence: As the children in a family grow to adolescence, they tend to crave more independence and privacy. Basements can offer adolescent children this independence and privacy.

4. Adolescence to Early Adulthood: As adolescent children grow to early adulthood, they tend to want control over their own space. At this stage in the family's development, basements are often converted to bedrooms and separate living space for young adults.

5. Departure of Children: As the children leave home to attend school, work or to marry, basement space is often recovered by the family for use as a family room, hobby room, etc.

6. Empty Nest: The departure of children is often accompanied by a feeling of loneliness and a decrease in income for their parents. At this stage, basements are often converted to accessory apartments that can provide a secondary income for the parents.

7. Divorce or Widowhood: Readjustments in family life often results from divorce or widowhood (either in the family or grandparents). Basements can be used to accommodate such divorced or widowed family members (or to provide space for children so that an elderly family member can be accommodated upstairs).

8. Return of Adult Children: Basements can also accommodate adult children who return to the family home later in life.

In view of the foregoing, Mr. Rodriguez summarized the benefits of good basements as being the following:

1. Basements are a multi-functional. They can accommodate activities that are inappropriate elsewhere in the house and changes in lifestyles (e.g. working at home with computer links to an external office).

2. Basements can provide additional income to a home owner. This is particularly important to first-time home buyers in urban areas with high property values and to older home buyers on a fixed income.

3. Basements make better houses.

4. Basements can enhance the marketability of a house for resale.

Mr. Rodriguez posed the question "How do we make it work?". He suggested that the architectural issues that should be addressed in making basements more habitable and useful are primarily the following:

1. The design of a basement must be integrated with the rest of the house, at minimum cost.

2. Separate access (i.e. direct exit) should be provided where possible.

3. Direct access to a basement from grade level (street level) is highly desirable.

4. Basements must be flexible and adaptable to the changes in the life events of a family.

5. Basements should be designed and constructed to accommodate easy and inexpensive modifications.

6. The fixed elements of a basement should be strategically located (e.g. the furnace) to permit optimum utilization of the remainder of the basement.

7. Appropriate utility outlets must be provided.

8. Hook-up possibilities for future basement modifications should be taken into consideration in the original construction.

9. Good natural lighting within a basement increases its utility.

10. The ability to control the environment of the basement (e.g. temperature, humidity, air quality, etc.) is essential.

At the end of his presentation, Mr. Rodriguez used a number of sketches to illustrate how natural lighting can be introduced into basements; how at-grade access enhances the utility of a basement; and how retail and office areas can be accommodated in basements. He also stated that the CMHC was currently involved in a study of 20 households in Montreal that should be completed early in 1989. In this study, the relationship between life events and the basement are being studied. Other issues that will be addressed in this Montreal study include zoning conflicts that inhibit the uses of basements, parking and servicing concerns with respect to "densification" of housing and "made-to-convert" housing.

Brian Gray - CMHC

In his presentation, Mr. Gray addressed a number of architectural utilization issues that affect basements. From personal experience, he believes that a half-depth basement offers many advantages over a conventional full-depth basement.

Half-depth basements provide for easier access to the exterior and make storage areas in basements more accessible. By cantilevering the first floor framing beyond the exterior foundation walls, basement windows can also be shaded from the sun.

Mr. Gray compared the cost of a 1,500 square foot bungalow with a 200 square foot attached garage to a similar house with a half-depth basement having a floor plan area of 1,000 square feet and a similar 200 square foot garage. His estimates indicate that a house with a half-depth basement could cost between $14,000 and $20,000 less than a bungalow with a full basement. Further savings might also be possible since a 1,000 square foot house with a half-depth basement could be constructed on a narrower lot than a 1,500 square foot bungalow.

Mr. Gray also indicated that a half-depth basement could be more readily converted to an accessory apartment than a full-depth basement. Half-depth basements are becoming especially popular in the United States.

At its upcoming conference in January 1989, the Canadian Home Builders Association will be demonstrating a "made-to-convert" house. Because of the possible cost savings, this type of house is generating interest both from municipalities and the home building industry.

Gerry Allen - Canadian Portlant Cement Association (CPCA)

Mr. Allen stated that the CPCA has long been active in research, work shops and educational programs to foster the proper use of concrete in the construction of residential basements.

In recent years, the CPCA has generally advocated the use of external insulation, crack control joints in walls and floors, and an increase in the minimum 28 day compressive strength of concrete required by Code from 15 MPa to 20 MPa. The CPCA also publishes educational literature and has prepared videos to train contractors in the proper use of concrete in basements. The Canadian Portland Cement Association and CMHC is also working closely with the developers of Codes and standards relating to the use of concrete in basements.

Mr. Allen expressed the view that a number of new developments with respect to the design and construction of concrete basements could find application in basements. These developments include the use of glass fibre reinforced concrete, the use of precast concrete sandwich panels below grade and entire precast concrete housing systems that include precast concrete basements. It is also possible that hollow core, prestressed concrete slabs could be used both for wall and floor systems in residential housing. These slabs provide internal cores for utility raceways and offer good thermal storage properties.

Mr. Allen stressed that the CMHC study should concentrate on practical improvements in basement technology that are capable of being implemented.

Tony Wellman - CMHC

Mr. Wellman presented the results of a recent study carried out for the CMHC with respect to technology transfer and innovation in the Canadian residential construction industry.

This study traced the length of time required for new technology to be fully accepted and adopted by the construction industry. The examples he used included gypsum wallboard, mobile cranes, plastic piping, etc.

The results of this study indicate that the Canadian residential construction industry has generally been slow to absorb new technology. Many new products and systems have taken longer than 15 years to be fully accepted by the industry.

Luc Cecire - NRC - Canadian Construction Materials Centre

Mr. Cecire explained that the Canadian Construction Materials Centre of the National Research Council offers the construction industry a national evaluation service for innovative materials, products, systems or services, in all types of construction. It was established in May 1988 and is fully endorsed by Provincial regulatory bodies.

A number of innovative products and systems applicable to basements have been evaluated by the CCMC at the request of their proponents. These include the following:

1. Synthetic drainage mats that can be applied to the exterior of foundation walls for moisture control.

2. Precast concrete wall panels patented by Mur Ebal.

3. Polystyrene blocks that can be filled with reinforced concrete and used in basement wall construction.

4. Light weight concrete containing polystyrene beads and polypropylene fibres that can be used for precast concrete wall panels.

During his presentation, Mr. Cecire circulated models and samples of these new products to those at the Symposium to describe their possible application to basements.

Al Houston - CMHC

In his presentation, Mr. Houston described how research into concrete forming systems may be able to improve the performance and reduce the cost of basements. Typically, the cost of forming and placing concrete for basement walls equals the material cost itself. Consequently, improved forming systems could reduce the cost of concrete basement walls significantly.

By advancing the technology of concrete forming systems, it should be possible to improve the finish and texture of the concrete, lower the cost of basements and incorporate additional engineering features into the basement walls to improve their performance.

Through the use of illustrations, Mr. Houston demonstrated how custom-designed forming systems might be designed to optimize the structural strength of both cast-in-place and precast concrete basement wall systems. Moreover, through the use of properly engineered plastic form liners, these types of forming systems could be reused up to 100 times to impart good quality finish and texture to such walls.

Mr. Houston suggested that the CMHC Advances in Basement Technology Study include an analysis of forming systems that could be developed for residential basements and challenged the study team to identify specific areas of research needed to develop such forming systems.

Fred Edgecombe - Society of Plastic Industries

Mr. Edgecombe stated that the plastic industry already produces many products to serve the housing industry. These include the following:

1. Fibre reinforced plastic form ties.
2. Plastic reinforcing bars.
3. Geotextile fabrics to cover weeping tiles.
4. Various types of insulation that can be applied to the interior or exterior basement walls.
5. Polystyrene insulation with drainage channels for moisture control and soil-gas venting.
6. Dampproofing products and vapour barriers.

Recent studies have shown that basement heat loss can account for approximately 26 percent of the total heat loss from a house. Consequently, careful consideration should be given to the type of insulation used for basements.

Light weight plastic ducting also appears to be ideally suited for use in basements to control moisture and to vent soil-gases.

Mr. Edgecombe stated that a number of leaders in the plastics industry are actively involved in research and development activities that should be of interest to the study team. Both BASF and Dow Chemical should be consulted since they have developed products and materials in other parts of the world that are still not being actively marketed in Canada.

Peter Mazikins - Canadian Wood Council

Mr. Mazikins briefly described the evolution of preserved wood foundations and used a series of slides to illustrate current PWF design and construction practices.

Preserved wood foundations that were developed early in the 1960's are now commonplace in many parts of Canada. They enjoy a special popularity in Western Canada. To date, approximately 60,000 houses have been built with preserved wood foundations.

Canadian manufacturers of preserved wood foundation materials now warranty their materials for 60 years. While the cost of PWF systems will vary with the design and location of a house, generally, they are comparable in cost to concrete systems. Yet, PWF systems offer the following advantages:

1. PWF basements require approximately 30 percent less heating and provide a dryer interior environment.
2. Interior finishes can be directly applied to the preserved wood wall studs.
3. PWF basements can be constructed very quickly.
4. PWF basements can be prefabricated and installed in severe weather.

Mr. Mazikins also described a number of developments that could affect the design and construction of PWF basements. To avoid confusion, a single standard is being developed that hopefully will replace the two current CSA standards.

While current Codes require the use of free-draining backfill and a 6 mill polyethelyne exterior membrane, the feasibility of using geotextiles in combination with painted-on membranes is now being studied. Currently, only stainless steel nails are permitted by Code, below grade. The use of galvanized nails in lieu of stainless steel nails is also being studied.

Paul Schurter - Dofasco

Mr. Schurter explained that Dofasco has pioneered the use of light gauge steel basements. The first steel basement was designed and erected by Dofasco in Regina, in 1971.

Mr. Schurter used a series of slides to illustrate the design and construction features of the Dofasco flat-rolled basement system. The exterior walls consist of 2'x8' galvanized sheets with a 3", rolled, floor-deck profile. These exterior sheets can be installed with a gravel drainage bed and steel footing; or with a conventional concrete footing with a steel footing channel. The steel components are connected using self-drilling, self-tapping fasteners.

A wood sill is installed on the top channel of the basement walls to accommondate the upper floor framing. Exterior insulation is impailed on pins that are field, butt welded to the exterior steel walls, above grade. An expanded wire mesh and stucco are then applied to the exposed exterior insulation. The floor of the basement is constructed of conventional concrete and the first floor framing beams are supported on steel posts.

The prototype work of Dofasco indicates that steel basements are competitive in price against more traditional systems and cheaper in remote areas. Based on their research, Dofasco does not deem cathodic protections to be necessary for the exterior basement walls. Moreover, the backfill does not necessarily need to be free-draining since the steel sheets can be designed to withstand the hydrostatic pressure of wet backfill.

Dofasco has not itself actively marketed the steel basement wall system that it researched and developed. Rather, it is waiting for others in the housing industry to actively market this concept.

John Timusk - University of Toronto

Professor Timusk is on contract to CMHC as an Advisor on the Advances in Basement Technology Study. He has also conducted previous work for CMHC that relates specifically to this study.

Professor Timusk presented those in attendance at the Symposium with an 8 page written brief entitled "Residential Basements - Issues". A copy of this written brief is appended to this Summary Report.

During his presentation, Professor Timusk invited the members of the Study Team to visit his offices in Toronto to review the technical literature that he has assembled on this topic.

David Eyre - Saskatchewan Research Council

Mr. Eyre is a member of the Study Team and during his presentation described the results of both previous and on-going research being conducted by the Saskatchewan Research Council on basement heat losses, soil temperatures and difficulties with retrofitting older basements.

Mr. Eyre presented a number of figures that illustrated the affects of insulation on the soil temperatures adjacent to basement walls. Insulated basement walls tend to exhibit flatter isotherms that increase the potential for energy loss from the perimeter of the basement floor slab. He therefore suggested that the perimeter of such slabs be insulated along with the exterior walls.

Moreover, the use of insulation applied partway down the interior of the basement walls can create a significant potential for heat losses from the remaining area, up through the walls and adjacent soil.

As part of their Provincial mandate, the Saskatchewan Research Council is frequently involved in public problem-solving involving residential basements. Mr. Eyre cited one example of a 60 year old house that was retrofitted with R8 insulation, a vapour barrier and finished on the interior. Because of short-comings in the original construction, this retrofit work allowed water to creep up the basement walls (dissipating heat rapidly), deteriorate the sill at the top of the basement wall and cause extensive water damage to the stucco on the exterior walls.

Mr. Eyre expressed the view that no "miracle solutions" would result from this study and that generally, better systems-designed systems are needed.

It may well be impractical to suggest that basements should be designed and constructed to provide all of the design features that are necessary to provide first-class living space in basements. He estimated that it could cost approximately $12,000 to upgrade basements to the extent suggested by those in attendance at the Symposium (e.g. large windows, 8 foot floor to ceiling height), truss joists to eliminate columns and interior bearing walls, electrical and plumbing upgrades, etc.).

Based on his experience, Mr. Eyre considers water problems to be the most significant to overcome in providing first-class basement space.

FIELD NOTES

Site visits were interspersed with the seminar sessions to allow up-to-date glimpses of field practices in A) concrete basements and B) preserved wood foundation (PWF) basements; and to show C) a new approach to providing liveable basement space completely isolated from the soil.

A. Concrete Basement Construction:

With full cooperation from the Canadian Home Builders Association and a housebuilder completing houses in the Ottawa area, the group was hosted to a brief tour of house sites showing basements at all stages from excavation to completion.

The general impression of good quality concrete work was offset by negative details, some of them attesting to today's lack of inspections by CMHC, the industry itself, the municipality or the lender:

- Insulating batts installed to 600 mm below grade on the interior with no barrier separating them from the concrete, no air seal at the lower edge, and no complete v.b. or final protective cover. (The OBC allows the last omission). Insofar as the insulation will work at all, it will encourage air-transported condensation and hence fungus on the cold surfaces of the concrete. (On the other hand, the looseness may well allow drying rather freely and thus avoid such problems in the general use).

- One-pass emulsion dampproofing on the exterior: tokenism that may be adequate on the particular site.
- A roof drain leader dumping to the drain tile, on one finished house, by way of a hole in the asphalt driveway against the house and a washed-out tunnel directly down.

(Above grade, on other houses, it was interesting to note again that the spun-bonded olefin cover on the exterior insulation sheathing was flapping loose in the breeze, clearly destined to defeat any attempt at taping or other make-good to make it function as the intended exterior air barrier).

B. Preserved Wood Foundation Construction:

The Canadian Wood Council's new "show home" in Nepean was visited under the auspices of the Council. While the emphasis on wood structure, claddings and features was all of interest, the group concentrated its attention on the PWF basement. Only the footings, in this case, were of traditional concrete. The gravel drainage pad, suspended wood floor and wood foundation walls were all open to view. An additional feature of interest, in this case, was the use of "Parallam" wood composite beams under portions of the main floor.

While the PWF work appeared well executed, ready for completion as a warm, dry and cheery living space, the wood frame construction below grade displayed the negative attribute that is still so common in site-built wood construction above grade: Wastage was rife, with the usual doublings and triplings of the required number of studs and cripples simply to fill space at corners, beam pockets and windows. While the wood product is a highly-doctored and costlier version of the common stud, the carpenters still throw it around in the traditional way.

C. The "Depressurized Inner Jacket" or ECHO Approach to Isolating the Basement from the Soil

A visit to the new home of NRC's Gint Mitalas provided an excellent introduction to this concept: Mr. Mitalas home features a pilot installation, supported in part by CMHC's House Technology Improvement Program. This particular version of the isolation concept has now been issued a patent as the ECHO (Enclosed Conditioned Housing System). An overall interior insulated "jacket" is built over the floor and walls, separate from the concrete by an airspace which is depressurized/ventilated by an exhaust fan. Moisture and soil gases entering through walls or floor are removed, by-passing the indoor air altogether.

The pilot installation entailed a $7,000 cost margin over the half-height, half-hearted insulation package normally provided to meet the Ontario Building Code. It offers assurance of basement indoor air quality more or less identical to that in the house above. (A significant part of the extra cost is due to Ontario's insistence that full electrical circuits and outlets be installed in any basement with full-height insulation, no matter what the intended use of the space. The cost represents the price of ready-for-finishing liveable space, not just the price of ensuring freedom from soil gases).

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RESIDENTIAL BASEMENTS

ISSUES

By

J. Timusk

The purpose of the following is to provide guidance to the consultant regarding the various issues concerning residential basements. It represents the writers views and the understanding of of the state of the art and is not complete nor necessarily correct.

SOME OF THE ISSUES

From the point of view of structural requirements a firm foundation is essential for the control of cracking and outright failure in extreme cases. (Loss of life due to foundation failure is unlikely when dealing with wood frame buildings - it is conceivable that a combination of factors such as a heavy concrete tile roof and earthquake might lead to loss of life - basement failure the writer has seen has been in the lack-of - serviceability category) In cold-climate countries frost heave has necessitated that for light buildings such as those covered by part 9 of NBC measures be taken to prevent frost from getting under the foundation walls. Hence a variety of approaches to control basal heave (where the frost gets under the footings) some of which have not been entirely successful. The most common solution was to take the footings below frost level.

Space between the ground surface and the ground floor has taken various forms, ranging from from non-existent in the case of early buildings with earth or flag floors to fully habitable space in the form of a basement.

Whatever the choice of foundation, it should function as intended. This has unfortunately not always been the case. Decay of floor constructions over unheated crawl spaces, water leakage, condensation of moisture on walls, frost have of foundation walls associated with unheated space, excessive energy consumption and entry of soil gas into habited space are some of the problems which unfortunately fall into the not-infrequent category.

Ideally those who design buildings and those who execute the design have all the relevant information to provide an optimum solution in terms of occupant needs, first and operating cost and to assure that the work is carried out so that the expected performance goals are indeed met. To the writer's knowledge no single document exists at the moment which would satisfy the above needs. It would not be realistic to ask for an all-embracive document which fulfills the needs of all concerned.

First of all, the required information does not always exist-there are many "white areas" where important components are missing and need to be provided through research and development. Next, the ability of the various constituencies to deal with the various concerns varies. Only when the issues are fully understood and solutions have been developed does it become possible to state them in simple language. Such language is often referred to as BUILDER FRIENDLY. User friendly might be a more appropriate term in that all concerned need to be able to use the document.

Before the point is reached where definitive solutions can be expressed in simple terms it may be necessary to rely on the judgment of experts in the field who can add the missing to an incomplete document. Hopefully most of the information concerning the present task can be expressed in a user-friendly form.

WHAT IS NEEDED

Most of the required information does already exist, albeit dispersed and often in a form suited for specialists only. It becomes then a question of assembling the required information and presenting it in a user-friendly mode. This, in the writer's opinion is made easier through a liberal use of figures. It is said that a picture is worth a thousand words, but at the same time it may take many pictures to describe what well-chosen words in a sentence convey.

Where solutions are too complex to be handled within the space available for this document the needs of the expert can be partially met through appropriate referencing. There is a fine line between too little and too much information.

The question of balance between prescriptive and performance approaches is not easy to establish but needs nevertheless to be addressed. The first is economical in terms of the use of space but limited as there is seldom one fixed solution. The performance approach is based on understanding the issues. Variations from a given condition can then be accommodated. It is of course the desirable approach but may not be practicable when space available to provide the understanding is inadequate. The consultant will have to exercise judgment in determining the balance between the two.

AN HISTORICAL OVERVIEW

In many of the older Canadian houses the basement was an afterthought, provided to house the coal furnace. Part of the crawl space became excavated to house the retrofit furnace and to accommodate the coal supply. Fully excavated basements were still merely damp cellars, often with a soil floor. After the first world war a significant transition took place. Perimeter drains were installed, walls became dampproofed and the quality of the space was improved. While still not of the same quality as above-grade space, the space did become habitable. The recreation room became the solution to pre-airconditioning hot summers. The basements were still damp during the summer. Heat loss was comparatively small-compared to uninsulated wood frame or masonry walls and attic space.

After the second world war the science of building improved significantly, largely due to the efforts of a few national building research establishments, notably DBR/NRC. (The consultant should pay particular attention to the relevant CBD's in that a great deal of effort has gone into the checking of the validity of the statements made and into providing at times complex arguments in simple terms) The insulation of basements is largely a post-73 phenomenon. The effect of insulation of basement walls became well established, control of water leakage and condensation of moisture were also understood but not generally accepted by the building community.

ENERGY CONCERNS AND THERMAL INSULATION

To calculate heat flow from the basement to the exterior one needs to know more than the thermal resistance of the elements along the heat flow path. Matters are complicated in that:

1. The heat flow path is of variable section and not straight (i.e. one is dealing with three dimensional heat flow)

2. The soil mass along the heat flow path is sufficiently massive to require that the heat capacity be taken into consideration and with it the latent heat of freezing/thawing associated with the formation of ice and its melting

3. The coefficient of thermal conductivity of soil is highly variable, being greatly influenced by the moisture content of the soil which itself is time-variable for a specific site and from site to site.

4. The flow of water which can carry away heat stored in the soil and which, in the case of freezing, can maintain a supply water and hence the latent heat of fusion to a slowly moving freezing isotherm.

In view of the difficulties of predicting the contribution of the soil to a specific location and the dominance of the the insulation in determining the rate of heat loss, perhaps some simplified methods for establishing the overall heat loss and hence the appropriate amounts and distribution of thermal insulation is all that one needs in the document to be developed. The Swedish building code provides a simple table where R-values are assigned to basement floor and wall elements for a few basic soil types.

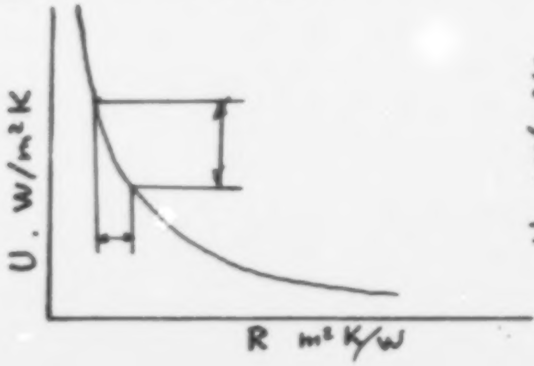
Once the basic decision to insulate has been made, the effect of a large error in the contribution of the soil to the overall heat loss is small if the the contribution of the soil to the total thermal resistance is small.

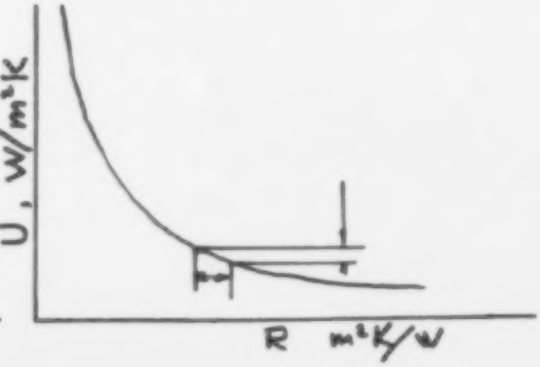
The selection of the location for the insulation, the kind of insulation, method of attachment and amount to be installed need to be established. In particular, an understanding of the consequences of thermal insulation on the performance of a structure need to be established, such as the effect of insulation on the temperature on other components making up the system and the sensitivity of the system to flaws. The "cutting of corners" may in some cases be acceptable but not in others.

In the case of basement floors matters become somewhat more complicated in that the heat flow path length may become sufficient to make the soil the major contributor to the total thermal resistance. Now, the need to insulate under the floor slab may not be obvious, especially if the contribution of the uninsulated slab to airconditioning is taken into consideration. Where, on the other hand the water table comes close to the basement floor the heat flow rate may become sufficiently high to fully justify underslab insulation.

The use of the slab and the soil below it for short-term thermal storage, the use of the floor as a moisture sink during the summer and a source during the winter and the control of soil gas and with it radon are some of the questions that need to be addressed. This is one area where practical solutions need to be developed-hence RDand D opportunities need to be pointed out if solutions can not be found from the literature.

The figures below show the effect of a marginal change of the R-value on heat loss. This, in the writer'sopinion is a case where a graph is essential.





MOISTURE AND LIQUID WATER

The introduction of thermal insulation and a better understanding of how hydrostatic pressure can be prevented from developing against basement walls render water leakage and condensation routinely controllable. What is needed here is a simple and concise document which provides the designers and the trades with the required knowledge. Industry has been remarkably tardy in absorbing new methods and materials when so doing would reduce the cost of building. For example, the crack initiators recommended in CAN A438, Concrete for Small Buildings and Housing would add very little, and according to some builders nothing at all to construction cost. They would eliminate the major home warranty complaint: cracked basement walls and water leakage through the cracks. Yet few builders have taken advantage of this method which would improve customer good will and reduce construction costs.

Now that radon gas has been recognized as a potential health hazard in Canadian housing, it may become possible to mandate changes to basement construction in the NBC, including the control of cracking and air leakage through the cracks in basement floors and walls.

Installation of perimeter drains and means of controlling silting of the same needs to be addressed. The use of filter cloths to control sitting or other methods in use in agricultural applications needs to be looked into.

If too much moisture was a concern in houses which were inadequately ventilated, then the reverse is starting to appear in properly ventilated houses. Whereas the use of a polyethylene vapour retarder under the basement floor slab was required to control moisture in inadequately ventilated houses, the old moisture problem-too little during the heating season is starting to reappear in R-2000 houses. One homeowner in Edmonton turned off his air-to-air heat exchanger because of the associated difficulty of maintaining an adequate relative humidity during the heating season.

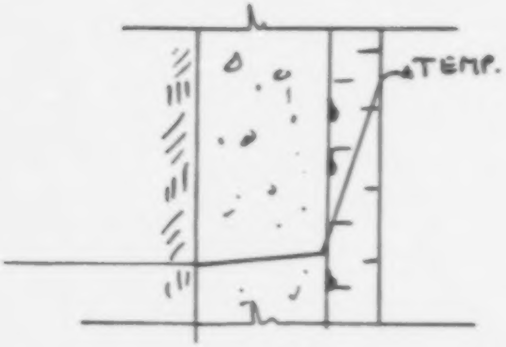
Once the entry of soil gas is controlled in the process of controlling radon gas in the habited space, one of the largest contributors to indoor moisture may also be eliminated.

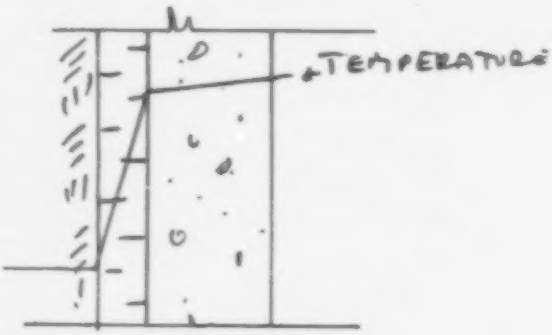
Whether to use polyethylene or not to use it will depend on a number of factors, such as the outdoor vapour pressure during the heating and cooling seasons, the need for air tightness control due to radon and the problems associated with concrete placement and finishing when polyethylene is placed directly under the floor slab.

It is possible that the floor slab could also be used as a moisture sink during the airconditioning season. The effect of thermal insulation and polyethylene vapour retarders on this potential needs to be taken into consideration. (What level of sophistication does one expect form the readers? In the writers opinion an understanding of the psychrometric chart is essential to the understanding of moisture control-yet architects and building officials objectead loudly to its use in one instance).

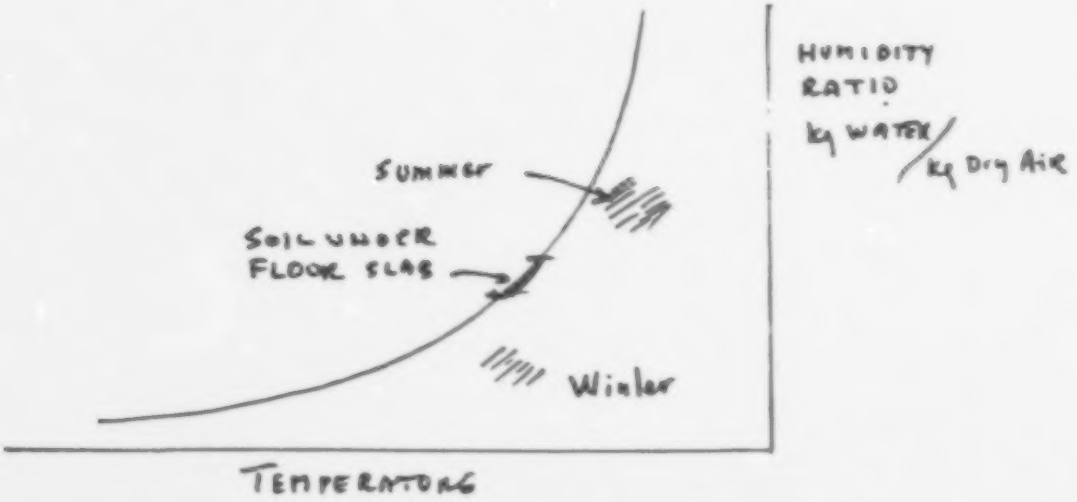
Examples of the use of the psychrometric chart to facilitate understanding of moisture control.

1. Location of the thermal insulation will determine where condensation could occur.





2. Use of the basement floor slab and the soil below it to supply moisture in the winter and absorb it in the summer.



SOIL GAS AND RADON

The recognition that soil gas may contain radon should be seen as a blessing in disguise. In the process of dealing with this potential problem we will be forced to ask a number of questions and provide answers to them. Many things we have taken for granted may be seen in a new light.

In our work on negative pressure houses (Dynamic wall houses) at the Centre for Building Science at the University of Toronto it has been necessary to closely examine the effect of an increased negative pressure on radon entry into habited space. In the process we have recognized a number of opportunities to couple radon gas control to new energy sources.

FROST HEAVE AND ADHESION FREEZING

While it has been reasonably well established that frost heave due to adhesion freezing is not a problem in the case of heated space, adhesion freezing damage to unheated foundations can occur. Also, when heated and unheated foundation walls are continuous, damage can occur due to the restraint of differential movement. This area is one where the mechanisms are relatively easily understood and can therefore be treated using the performance approach.

Slabs on grade are likely to become more common, particularly when they become permitted in the National Building Code.

LAND USE, SPACE AND ECONOMICS

The optimum solution takes into consideration all of the relevant parameters. A need for radon control only arises when basements are placed in a soil which can supply radon gas; the excuse for basements, the need to take the footings below the depth of frost penetration may not be particularly convincing in Costal B.C. or where the water table is very high.

In the writer's opinion the examination of building form with respect to occupant preferences and land cost realities is the area where the greatest contribution can be made in this study. For example, where land costs are very low, a slab on grade solution may be viable; where energy costs are extreme or if extreme energy costs are anticipated, a building which minimizes the thermal envelope to building volume ratio is preferred.

In areas where the the cost of land is becoming prohibitive the building frontage to volume ratio has to be minimized. Yet there are limits to how narrow a building can be: if it is too deep then the availability of natural light may be insufficient. If it is too high, the occupants may complain about having to climb too many stairs. A three storey building with slab on grade may be objectionable yet entirely satisfactory if entry is to the middle storey from grade level and the basement forms one of the storeys.

Interesting solutions of rowhousing developments where balanced cut and fill make it possible to provide middle storey street level entry at grade while the first storey has a slab on grade at the back of the building.

All have land use, construction, energy and soil gas implications.

APPENDIX B

HISTORICAL PERSPECTIVES

APPENDIX B

HISTORICAL PERSPECTIVES

1.1 Evolution of Basements

It is an oversimplication to think of basements evolving in a consistent gradual process that took place simultaneously across Canada. Rather, the types of foundations used during the early periods of Canadian development depended to a large extent on the economic circumstances that prevailed in each particular area. At any given period, various types of foundations and basement construction co–existed across the country in various stages of the evolutionary process.

Pioneer communities, for example, tended to have more primitive foundations than in established communities. Material and labour availability as well as personal affluence also played an important role in determining the type of foundation or basement used for each house.

Many earlier pioneer dwellings had no basements but were constructed on mud sills supported directly on the ground or on simple stone piers. In some of the poorer areas, houses were constructed with dirt floors at least on a temporary basis until sufficient resources could be found to provide a proper floor. Generally, settlers chose higher ground to stay dry, but that choice was, and is, sometimes more limited in urban clustering.

As the land was cleared, however, and farming developed, basements (or cellars as they were originally known) became a necessity to provide frost–free storage for vegetables after the fall harvest.

Many earlier rural cellars were little more than large holes excavated beneath the floor with exposed earth floors and, in many cases, exposed earth walls where the cellars did not extend to the perimeters of the buildings. Footing drains and other means to control water and moisture entry were virtually unknown. To reduce the danger of water entry, basement excavations were kept shallow. Little headroom was provided and the first floor was usually kept well above ground level. As settlements flourished and the quality of housing improved, mudsill and pier foundations gave way to more permanent foundation walls of fieldstone or rubble although brick and cutstone were also used where these were available and the owner could afford them. Foundation walls enclosing basement space generally extended down below the level of the frost penetration to provide a more stable support for the superstructure. This became more important as the interior finish evolved from exposed logs or boards to the more friable lath and plaster finish. In many cases, houses originally constructed without basements were later retrofitted with more permanent foundations including full basements.

Although Portland cement was patented in 1824, it did not come into general use in North America until the invention of the rotary kiln in 1882 which permitted its mass production. Consequently, most earlier permanent type foundations were constructed from natural or cut stone or brick laid in sand–lime mortar.

Early foundation walls were generally of substantial thickness based on rule–of–thumb design principles with little or no thought given to engineering principles. Brick walls were generally about 300 mm thick while stone walls were from 300 to 400 mm thick depending on the surface regularity of the units.

As concrete and concrete blocks became available in the early 1900's, the use of brick and natural stone declined. The last references to requirements for natural stone foundations appeared in the 1963 edition of Housing Standards, although the actual use in construction was probably discontinued much earlier.

The early part of this century also saw the development of central heating systems for Canadian houses, generally based on convection or gravity flow of warm air or hot water. The basement or cellar was the logical place to locate such systems since they relied on the furnace or boiler being at a lower level than the spaces to be heated. The basement not only provided ample space for the bulky heating equipment but provided convenient storage space for the wood and coal as well.

Early basements (or cellars) were usually dark, damp and cramped. Their sole purpose was to provide a space for storage and for central heating equipment. In summer, they also served to provide a cooler storage space for perishables such as dairy products in houses that lacked ice boxes; through the fall and winter they helped to maintain root crops and fruit for which low temperatures and dampness were beneficial. These cellars were ideal for this purpose.

Bare earth floors continued to be common, particularly in modest housing, even though concrete was available for floor slabs. This practice continued well into the early half of the century and generally died out by the 1940's; in some areas, changes began to occur in well–to–do areas one or two decades earlier.

About the 1940's, several events occurred that had a major influence on house construction generally, and most noticeably on basement construction. These included the development of the first model National Building Code (1941), the proclaiming of the National Housing Act (1944) and the creation of Central Mortgage and Housing Corporation (1946). These will be discussed in more detail later. In general, the codes and regulatory bodies tended to pick up and "normalize" the changes already adopted by builders.

Through the influence of these events, basement construction practices were generally upgraded. Basements were provided with footing tiles for foundation drainage. Dampproofing of the walls became a general requirement, and the floors were required to be covered with concrete slabs over granular bases. Minimum headroom requirements were also introduced. Ice boxes and then refrigerators took over the job of preserving food. All of these changes served to promote and allow a change in quality of the cellar to become dry basement space of broader and higher usefulness. The increased quality of the space soon made it the prime location for laundry services as well as a general utility area. Some basements were partially finished to provide additional recreational space and for additional bedrooms. By 1970, about 8% of all new NHA houses were built with either partially or fully finished basements. Although current statistics are not available, it would appear that current figures would be much higher.

The energy crises in the early 1970's focussed attention on basements for potential energy conservation. Prior to this, little attention was given to the need to insulate basements, particularly if they were unfinished. The energy crisis, however, caused various government agencies in the latter 1970's, including CMHC, to mandate the insulation of basements as part of a general program of energy conservation. This period also witnessed the development of preserved wood foundation systems. Initially a Canadian innovation of the early 1960's, the system was developed for practical use by the U.S.A. in the early 1970's. Following its acceptance for use in NHA Construction in 1974, it was accepted for use under the National Building Code (a year later). The prevailing concerns about energy conservation encouraged its introduction because of the ease with which frame walls could be insulated and finished. Although accurate current statistics are unavailable, industry estimates claim its use in about 10,000 houses per year.

Few substantial developments in basement construction have occurred since the introduction of preserved wood basements in the 1970's. Although new waterproofing and dampproofing materials have been introduced to the marketplace as well as vertical surface drainage materials, these have not materially changed typical basement construction practices.

1.2 Regional Preference

Throughout the history of basement evolution in Canada, regional preferences appear to have played a significant part in shaping construction practices. Many factors were at work including regional climatic conditions and soil conditions, availability of construction materials and special trades, local traditions and the general prosperity of the region.

One preference that all regions have in common, however, is that all current information reflects a strong preference for basements. Even in British Columbia, where the percentage of basementless houses is highest, at least 55% of the houses in 1955 were constructed with full basements. By 1970, this increased to 88%, which is close to the national average (90%). Although recent statistics are unavailable, general observations indicate that this situation currently prevails.

Concrete Block vs. Cast–In–Place Concrete

Although both cast–in–place concrete and concrete block have been available since early in this century, cast–in–place concrete has generally been the material of choice in most regions.

Concrete basement walls could be formed relatively easily by carpenters who were available in most communities. Concrete block, on the other hand, required a mason's skill for economical construction. In Ontario, a large labour pool of skilled masons was available, a result of its traditional preference for masonry houses, particularly in the southern regions. Concrete block was abundant and relatively economical, so that in Ontario the economical balance was initially tipped in favour of concrete block. By 1955 about 74% of NHA houses in Ontario were constructed with concrete block basement walls, while in the remainder of the country about 96% of the walls were of cast–in–place concrete.

The increasing cost of on–site labour, the development of more efficient forming systems, and the general availability of convenient transit– mixed concrete (by the mid 1950's in some areas) combined to reverse the economical balance in Ontario towards cast–in–place concrete. The relative strength of cast–in–place concrete in comparison to concrete block also favoured the choice of the former as basement walls were required to sustain greater earth pressures. This resulted from consumer demand for greater headroom and the growing architectural preference for locating the ground floor closer to finished grade. The increased thickness of concrete block required to support the lateral earth pressures widened the cost gap between the two materials.

By 1970, the use of the concrete block foundation walls had declined to 27% in Ontario while in the remainder of the country, the use of cast–in–place concrete was relatively steady at 97%. Observations indicate that the percentage of houses with cast–in–place concrete foundation walls constructed in Ontario are currently approximately the same as in the other provinces of Canada.

Wood Basements

The introduction of preserved wood basement walls in the 1970's appears to have created another regional variation in basement construction, being much more common (on a percentage basis) in the western provinces (particularly in the prairie provinces) than in the atlantic or central provinces. Observations indicate that most wood basements currently being constructed, are in the western provinces. The reason for the greater popularity in the west is not known with certainty, although several factors are suspected. Material availability, relative cost, and consumer acceptance would all appear to play significant roles. The more aggressive marketing by the western plywood and lumber interests in promoting preserved wood also appears to have been more successful in the west that in the east.

Another factor that may have influenced western acceptance is their climate. Although preserved wood foundations are generally as expensive as concrete, they facilitate the space–saving installation of insulation without the need for additional framing. The relatively severe Prairie climate makes this aspect especially attractive to Prairie home buyers. Based on industry estimates of 10,000 preserved wood basements per year, this would indicate that about 7% of new houses have preserved wood basements (assuming that such basements are generally restricted to one and two family houses).

Reinforced Concrete

Soil conditions are responsible for at least one variation in basement construction. Various regions in the Prairie provinces have unstable soil conditions that require special construction to ensure satisfactory foundation performance. In 1955, for example, about 70% of all house foundation walls in NHA houses in Manitoba were reinforced. By 1970 about 60% of foundation walls in Saskatchewan were also reinforced to reduce structural damage. Very few basement walls in the other provinces were reinforced at that time. No statistical information is available on current practices, however, but it appears that reinforcing is generally absent except in unstable soils where it is clearly desirable and economically justified.

Beam Fill Construction

Typical practice throughout most of Canada is to place concrete in the formwork before the floor framing is erected. After the forms are stripped a sill plate is anchored to the top of the concrete and the floor framing nailed to this plate to provide anchorage for the superstructure and lateral support for the foundation walls.

In certain western provinces however, the floor framing is installed on top of the wall forms before the concrete is placed and supported at midspan by posts and beams. Blocking is placed between the joists near the interior forms, and a header or band joist nailed to the ends of the joists at the exterior forms. When the concrete is placed, the ends of the joists are embedded in the top of the concrete, making additional anchorage unnecessary. This so called "Beam Fill Method" insures support for the top of the wall during backfilling. With the subfloor in place, this method not only provides an enclosure for winter heating, but allows the floor assembly to be used as a platform for wheeling the concrete to the perimeter forms.

Other minor variations in basement construction practices also occur from region to region, including variations in forming practices, methods of interior dampproofing, location of footing drains and the installation of insulation. These, however, are considered to be relatively minor.

1.3 Codes and Standards

Prior to the Second World War, no comprehensive national or provincial guidelines existed for house construction. The regulation of buildings under the British North American Act, being a provincial responsibility, was generally delegated to municipal governments. Many municipalities had no by–laws to control building construction or had by–laws that varied in quality and coverage, depending on the technical resources of the community.

In order to create some order out of this melange of requirements, the joint committee of the Federal Department of Finance and the National Research Council was established for the purpose of developing building regulations that could be used as a model for all municipalities in drafting their by–laws. As a result, the first National Building Code was published in 1941. These requirements had no legal status unless adopted by individual jurisdictions. The National Building Code was first used as the minimum standard for houses built by Wartime Housing Ltd., a crown agency responsible for the production of houses needed in support of the war effort. Widespread adoption of the National Building Code by municipalities, however, was somewhat delayed because of the war.

Of more immediate impact on house construction was the passage of The National Housing Act in 1944 and the establishment of the Central Mortgage and Housing Corporation in 1946 to administer the Act. The year following the establishment of CMHC, it issued its first Building Standards to be used as minimum requirements for houses built under the NHA.

The requirements for basements in the model Code varied somewhat from those in the CMHC Building Standards, and both showed a lack of appreciation of engineering principles in their structural requirements for basement walls. Both sets of requirements however, were fairly comprehensive regarding drainage, dampproofing, the need for floor slabs and minimum ceiling heights. The differences that existed between the two sets of requirements were therefore relatively unimportant in light of the role that both played in improving the general quality of basement spaces.

While the Building Standards applied to everyone building under the National Housing Act, the NBC requirements were voluntary and were introduced gradually as more and more communities became convinced to adopt them. In addition, those building under the NHA not only were required to submit plans for checking, but were subject to fairly rigorous field inspections by CMHC which was usually much more thorough than municipal inspections. While certain revisions were made to the structural requirements for basements in subsequent editions of the Building Standard, it was not until the responsibility for building standards was passed to NRC (and its ACNBC) in 1958 that substantial revisions were introduced for basement construction. On the basis of engineering analyses and comparative studies of the requirements of these agencies, basic changes were introduced to provide more realistic structural requirements. These reflected the fact that lateral soil pressures rather than superstructure loads were the prime determinants of minimum wall thickness. The net result was that significant reductions were introduced regarding the thickness required for cast–in–place walls which helped to tilt the economic advantage in their direction.

The CMHC Building Standards were replaced in 1958 by the NRC Housing Standards when responsibility for building standards was transferred to the NRC. The Associate Committee on the National Building Code was given responsibility for the Housing Standards soon after, and published its version in 1962 under the same name, and as the Residential Standards in 1965. Under the ACNBC the requirements came under the scrutiny of specialist committees backed by the technical support of NRC, through its Division of Building Research. Many studies were carried out, and as a result many changes introduced to rationalize the various requirements based on engineering principles, as well as past experiences.

In 1970, the requirements affecting health and safety in the Residential Standards were included in the National Building Code in Part 9, Housing and Small Buildings, thus finally eliminating the residual differences between the National Building Code and the Residential Standards.

As additional municipalities adopted the National Building Code, provincial interest in building regulations also grew, and one by one the various provinces began to contemplate provincial building codes, based on the NBC model. Provincial governments began to withdraw the authority delegated to the municipalities to pass their own building by–laws. Currently, most provinces use the National Building Code by reference or have enacted provincial codes based on the national model. Only Newfoundland and Prince Edward Island are without such provincial building regulations, although even in these provinces, most major muncipalities have individually adopted the National Building Code. The Residential Standards, (last published in 1980) are no longer issued by NRC, but NRC's research continues to support the Code itself as well as the various standards which it references.

Towards the latter part of the 1970's increasing attention was given to the insulation of basement walls as part of the national energy conservation programs. The insulation requirements in Residential Standards were removed in favour of the more extensive requirements developed by the ACNBC in their "Measure for Energy Conservation in New Buildings". These recommended the insulation of all basement walls. Since insulation requirements were not considered to be related to health or safety, they were not included in the National Building Code.

The new energy conservation "Measures" were not widely adopted by legislating authorities (except in Quebec) but they did influence the requirements issued by CMHC and other federal government agencies. Certain other provinces including Alberta and Ontario introduced insulation requirements that included house basements and these remain in effect.

Federal programs, in particular the R–2000 program, also encouraged basement insulation but went much further than the requirements in the ACNBC "Measures". This helped to focus additional attention on the need to insulate basements. Manuals were published and educational programs introduced in an attempt to steer the building industry towards greater energy conservation in houses.

As interests developed in wood basement construction, the Canadian Standards Association took the lead in developing a new national standard for preserved wood foundations. By referencing this standard in the National Building Code (and the various provincial codes based on it) preserved wood basements are regulated without including these requirements directly in the Code.

Since the initial introduction of the requirements for basements, many changes have occurred in the National Building Code and its provincial counterparts. Public expectations have changed and additional technical information has continued to develop. Codes and standards are coming under closer public scrutiny and are becoming increasingly sensitive to public reactions. The net result is that the quality of basement space, (along with other aspects regulated by codes) is improving.

Amongst the changes being proposed for the 1990 edition of the code are attempts for the first time to address the growing concerns about radon and other soil–gas seepage into basement spaces.

1.4 Quality Control and Code Enforcement

Building regulations alone can not ensure that a quality house will be built. Unless an effective enforcing mechanism is in place, the provisions of any code may be misunderstood or ignored, and the owner left entirely in the hands of the contractor or his subcontractors.

The introduction of building regulations and standards after the Second World War occurred when little expertise existed in the policy of building regulations. Previous to the war, there was relatively little house construction activity, and home owners depended on the skills and integrity of the craftsman to provide an acceptable product. Building departments were not common and those that existed generally showed little interest in house construction.

The entry of CMHC into the standards enforcement field after the war, had the effect of greatly increasing the pool of expert housing inspectors. The comprehensive inspection system initiated by CMHC (which included inspector education) contributed significantly to the quality of NHA housing. This service included plans checking as well as on–site inspections at key stages in the construction. The large number of inspectors spread across the country established a valuable feed–back of information that also enhanced the effectiveness of the service. This service while aimed specifically at NHA housing, had a ripple effect on non–NHA housing as well. By helping to spotlight construction errors or poor practices, it served to help educate the local builders who were also involved in non–NHA houses. Competitors not operating under NHA were also forced by their competition to follow this lead.

The development by various industries of new products or systems that were not specifically covered in existing standards led to the establishment of a materials acceptance service by CMHC. This service, assisted by the technical input of other agencies such as NRC, also contributed significantly to the quality of houses by ensuring that new products were adequately investigated before being used. While primarily directed at NHA houses, the service was used by many municipal building departments as well. Designers and prospective home buyers trusted the objectivity of the Corporation and also made use of the service. In effect, it became a defacto approval service for the country, and a means for introducing new products on a national scale.

The zenith of CMHC leadership in the policy of housing regulations and in promoting the quality of houses however has now passed. For a number of years CMHC has been reducing its role in the inspection of houses, relying more on the growing expertise of municipal and provincial building departments. More recently the Materials Acceptance Division has been removed from CMHC and relocated at NRC's Institute for Research in Construction (the successor to NRC's Division of Building Research) under the name "Canadian Construction Materials Centre". Its expanded role is intended to serve the evaluation needs of provincial authorities using the National Building Code as well as NHA housing.

Since the standards used by CMHC (as far back as the 1965 Residential Standards) were essentially the same as those in the National Building Code, it may be said that the role played by the CMHC inspection and acceptance activities in the quality control of houses aided in the general acceptance by the municipalities of the National Building Code as well. Houses inspected under NHA auspices could also be assumed to meet the NBC and this reduced the work load of the municipal authorities substantially. Many authorities in fact depended most completely on this service.

Initially, municipal inspection services were generally slow in developing. Many were literally not equipped technically to enfore the code that they voluntarily adopted. While some of the larger communities did in fact have competent staff, many just did not have the resources to enforce their adopted building by–law effectively.

However, as provincial code adoptions progressed, some provincial authorities took an active role in developing effective provincial agencies to help enforce these regulations. These agencies not only established effective educational programs to upgrade inspection skills, but provided a source of technical and legal advice for the municipal inspectors, particularly in smaller centers. The technical services provided by NRC as part of its commitment to the development of the National Building Code was available to all code users as well, including the provincial agencies.

Yet, in spite of developing expertise in municipal and provincial inspection services, the net effect of CMHC's withdrawal from the policing of technical requirements has on the whole been a negative one. This has been evident in visits by the consultant to housing sites that relied solely on muncipal inspections.

The quality control exercised in basement construction varies significantly from one muncipality to another, and from one province to another. While many areas maintain consistant, high levels of construction, others tend to rely heavily on the skills and integrity of the contractor.

In an attempt to improve consumer satisfaction, many parts of the country have introduced home warranty programs. These are essentially insurance programs where for a fixed fee certain repairs and other benefits are guaranteed over a fixed period of time. Such programs are operated either on a voluntary or mandatory basis, but generally with the involvement of the house building industry: there is at least a tacit, and increasingly, realization that the house producer should take some responsibility for the quality of his product. It is considered that these have generally been effective in protecting buyers from the more flagrant abuses of untrained, inexperienced or unscrupulous home builders.

1.5 Incidence of Basement Problems

The problems that mark the basement as the major single source of home buyers' complaints are not all moisture problems, but the majority are moisture–related and of most concern here. The structural problems – shrinkage and settlement cracks in walls and floors, honeycombing of concrete, and some incidence of displacements and failures – are addressed among the issues in the next section. Special problems, including sulphate attack of concrete, and design and construction problems in permafrost areas and expansive soils regions are specific problems that extend beyond the scope of this study.

Concentrating on the production of liveable basements, the moisture problems of most concern are those of insulated, energy–efficient basements below–grade. A survey was conducted in 1984 to determine the incidence of problems induced by basement "energy retrofit". This survey drew input from 148 municipal building officials and 102 building specialists, covering an estimated housing sample of about 500,000 units. Fewer than 50 problem cases were identified, and many of these could not be positively authenticated as being retrofit–induced. The specialists were able to verify five or six problem cases that could be attributed directly to energy–efficient retrofits. However, the survey was not set up to look within the insulation and framing on the interior of the concrete wall.

The incidence of real moisture damage still remains questionable. In most houses of modern construction the concrete and block masonry is fairly sound and adequately dampproofed, and the rate of moisture movement through the concrete is relatively slow. Since most basement retrofitting has been applied to the interior of the foundation wall, the results of this moisture migration will not be immediately visible. Thus, the findings of the above survey – which did not include investigation inside the insulated cavity – should be treated with caution. In field work on moisture–troubled new houses where such investigation was sometimes included, excessive mould and wood deterioration were found (i.e. Atlantic Provinces).

At low rates of migration it may take several years for moisture damage to become evident through rotting, odour, mildew or discolouration. This process will obviously be aggravated by any deterioration of the dampproofing. Seepage or condensation in the insulated space, and entrapment by the interior and exterior barriers, can encourage fungal growth, particularly where insulation is applied over the full height of the wall.

In older houses with no dampproofing and deteriorated concrete, the problem of retrofit–induced moisture damage can be seen in accelerated form. One such instance was reported recently in a two–basement study conducted in Saskatoon. Similar conditions were seen in houses in Newfoundland.

Water passed through the deteriorated concrete and created a saturated vapour condition in the sealed airspace between the concrete and the new interior retrofit structure. Eventually, this would also have created extensive moisture damage within the new structures. At the same time the sealed airspace inhibited the inward dissipation of moisture and diverted the moisture flow upwards, towards the sill plate and the wood frame structure above. In Saskatoon this became evident within a very short period in the form of water discolouration on the exterior stucco. (The wicking up of ground water probably adds to the supply and in this and similar situations, concrete spalling has been noted.)

The possibility of concealed long–term moisture damage cannot be ignored, and the causes of these problems will be moisture penetration from the outside, condensation from the inside, wicking, and inadequate moisture dissipation outside and inside. The obvious solution is to eliminate exterior moisture penetration as far as possible, while at the same time providing a dissipation path on the interior. By happy coincidence, a design that achieves this will also go a long way towards solving the problems of soil–gas entry.

Exterior insulation/drainage: The Scandinavians focused on the opportunity of gaining liveable space affordably below grade in the early 1960s. Their work with lightweight gas concretes began to show the advantages of insulating the basement but also drew more attention to the moisture problems. Despairing of the traditional token dampproofing approaches using asphalt compounds ("black magic", they called it), researchers in Sweden turned to an external layer of mineral fibre insulation as a combined capillary break and thermal insulation outside the gas concrete block structure. By the later 1960s, it was evident that the new combination could work well, indefinitely.

Norwegian researchers pushed a similar application further. Drawing upon the success of their agricultural colleagues (in using mineral fibre layers as field tile filter–covers), the building scientists deployed mineral fibre as a complete drainage layer down the basement wall and over the drain tile. They proceeded to prove, by 1970, that the layer functions well without "silting up" itself or the tile, while providing a capillary break and good thermal performance as well.

Visiting researchers from Norway and Sweden were apprising their colleagues in National Research Council Canada of this work in the 1960s. While doubts remained about the long–term avoidance of silt blockage, the overall cost status compared to interior insulation, and the need for full–height insulation, the technical elegance of the exterior combined–function approach was readily appreciated.

Dr. Timusk, head of the University of Toronto's Building Science Centre, worked with some of the Scandinavian pioneers and has supported the trial and adoption of the exterior approach in Canada, through the Canadian Home Builders Association and others. As will be seen in the next Sections, the use of a combined external insulation/drainage layer is brought to the fore in this study as one technological advance worth considering for practically any advanced basement system.

APPENDIX C

ISSUES FUNDAMENTAL TO IMPROVING BASEMENTS

APPENDIX C

ISSUES FUNDAMENTAL TO IMPROVING BASEMENTS

1.0 FUNCTIONAL ISSUES

1.1 The Expanding Function of Basements

The function of basements in Canadian housing has changed considerably in the post–Second World War period. This change has been stimulated by advances in technology as well as by increased affluence and changes in the life–style of Canadians.

Basements built in the 1940's and 1950's, were generally not intended to serve as prime–living space; but rather, as ancillary, service and work and storage space. During this period, furnaces were often located centrally within a basement. Since many of these furnaces were fueled by coal and oil, coal bins and oil tanks were also frequently accommodated in the basement. The perimeter areas of the basement were typically allocated for use as a laundry room, pantry, work room and storage area. In the southern regions of Canada, such basements were also used to accommodate a summer kitchen and sleeping areas for use during periods of hot weather.

Because of the predominant service and work functions of these earlier basements, they were generally not partitioned into rooms or finished as living space. They were also most often built with a substandard floor–to–ceiling height (which was further restricted by suspended furnace ducts).

As the babies of the post–Second World War baby boom reached adolescence in the late 1950's, it became popular to convert an area of such older basements into a recreation room. This type of conversion was facilitated by a trend towards replacing older coal and oil–fired furnaces with more efficient and more compact gas and oil -fired furnaces complete with rectangular duct work that increased the floor–to–ceiling height clearances in these basements.

The basements of new houses built in Canada in the late 1950's and 1960's reflected various advances in technology as well as the growing affluence and changing life–style of Canadians. The more significant of these changes are described below:

1. The popularity of basement recreation rooms led to the more efficient allocation of space for services in basements and to increases in the floor–to–ceiling height of basements.

2. Residential heating units were reduced in size and no longer centrally located in the basement. Electric baseboard and radiant heating systems that eliminated the need for central heating units entirely also became popular in some regions of Canada.

3. Automatic clothes washers and dryers that could be accommodated conveniently on the first floor of a house became popular. This reduced the need for a laundry room in the basement.

4. The convenience, quality and affordability of canned and frozen foods led to a reduction in home canning. This factor combined with a trend towards air conditioning reduced the demand for summer kitchens in basements.

5. The advent of the attached garage in Canadian houses provided convenient, at–grade space for storage and work areas. This reduced the need for such space in basements.

In combination, the foregoing factors have dramatically altered the function of basements in Canadian houses. As the need for service and work space in basements decreased, more of the basement could be allocated to living space. During the 1970's, split–level house designs became popular because they extended living areas from the first floor into otherwise under–utilized basements.

Any new or improved materials, methods or systems that are advanced for the purpose of improving basements must be evaluated on the basis of their ability to accommodate the multi–purpose functions of basements. Ideally, any such advances in basement technology should be directed at improving basements to the extent required to accommodate not only service and work space, but space comparable in quality to living space on the upper levels of a house. Only then can basements be utilized to their fullest potential.

1.2 Adaptability to Life–Style Changes

Recent studies conducted by the CMHC and others have confirmed that basements offer an enormous potential to satisfy the changing life–cycle needs of a family. Mr. Louis Rodriguz, of the CMHC presented an overview of this issue at the symposium on Advances in Basement Technology held at the CMHC National Office in Ottawa on 20 September 1988. A summary of his presentation is appended to this study.

The primary architectural utilization issue pertaining to basements with respect to life–cycle needs is adaptability to retrofit changes. First– time home buyers are most often young adults who have limited financial resources and who require only limited dwelling space. Unfinished basements offer such home buyers the opportunity to expand their living space as their financial circumstances improve and their need for living space increases. Alternatively, by finishing such basements to auxillary apartments, first–time home buyers can generate needed rental income (particularly in urban areas where demand for such rental units is high) to help finance the purchase of a house.

New and improved materials, methods and systems for improving basements should be evaluated on their ability to adapt to such life cycle changes, at the lowest possible initial cost. To meet this goal, basements built for conversion should have an adequate floor–to–ceiling height; be unencumbered by interior load bearing walls and columns; have exterior walls that are problem–free; and be serviced with rough–in plumbing and electrical services, that will facilitate conversion of basements to suit changing functions. Provisions must also be made during the initial construction of the basement to ensure that the environment within the basement can be made comparable in quality to that available on the upper floors of a house.

1.3 Integration with Upper Floor Space

If the potential of basements is to be fully realized, basement space must be properly integrated with the upper floor space of the house. The architectural issues surrounding such integration are similar to those involving the upper and lower floor integration of spaces in two–storey houses.

If basements are to be capable of meeting the changing life–cycle needs of a family, consideration must also be given to how the integration of basements with upper floor space can be altered periodically to adapt to such changing needs.

Fundamental to improving the integration of the basement with the upper floor space is the ability to improve the appearance and utility of stairways connecting these spaces. Split level designs facilitate such integration of space and have also been demonstrated to be adaptable for use as auxiliary rental apartments.

The integration of utilities is likewise an issue that must be considered. New and improved materials, methods or systems proposed for basements should ideally facilitate life–cylce changes within such convertible houses.

1.4 Access and Egress

Safe, convenient access and egress to and from basement space is of fundamental importance to optimizing the utilization of basements. If basements are to realize their full potential as living space, provisions must be made in their design to ensure that their occupants can exit a basement as safely as occupants on the upper floors of a house, in a fire or other emergency. Due consideration must therefore be given to the number and location of exits and to providing fire separations between these exits and the upper stories of the house.

Any new or improved materials, methods or systems proposed for improving basements should be capable of accomodating walk–outs that exit directly to the exterior of the house from the basement. Direct access to the exterior from a basement should remain a viable architectural option with any new or improved foundation wall systems that are proposed to advance basement technology.

While it may not be practicable to make provisions for all of the access and egress requirements for the basement required throughout its useful life, during its initial construction, it should be possible to retrofit such requirements into a basement, as and when required, to suit life–cycle changes of a house.

Raised basements are common in some regions of Canada. Since larger windows can be accomodated in the exterior walls of raised basements, it generally should not be necessary to provide more than one exit door from these basements, for the safety of occupants.

1.5 Natural Lighting

Natural lighting is an important architectural feature for residential living space. If basements are to realize their full potential, practical means for increasing natural lighting in basements must be developed.

Shallow basements are best able to meet this need. However, shallow basements do not enjoy widespread acceptance amongst home buyers across Canada. Houses with shallow basements have raised first floors that elevate access to the primary living space and affect the exterior elevation of a house.

In deeper basements, larger windows can be accomodated only through the use of window wells. However, while they provide natural lighting, they do not afford basement occupants an enjoyable view to the exterior. Window wells have also been the source of structural, moisture and maintenance problems in older homes.

In recent years, large basement windows in urban areas (particularly urban areas in the United States) have become access points for burglars. Many such older windows have been retrofitted with glass blocks to avoid this danger. However, while these glass blocks have been effective in stopping intruders, they also preclude the use of such windows as emergency exits for basement occupants.

New methods, materials and systems proposed for improving basements should enhance and not preclude increasing the natural lighting in basement areas. Ideally, they should provide the means for increasing natural lighting without compromising the structural sufficiency or security of the exterior walls. The development of Light Pipe Systems for this purpose could be considered.

1.6 Interior Finishes

The architectural issues surrounding the wall, floor and ceiling finishes of a basement generally mirror those in the upper stories of a house. Service and work areas in basements require durable finishes that are not easily damaged and that require little maintenance. The finishes in living areas of a basement should be comparable in quality to those accepted for use in upper floor living spaces.

While conventionally formed concrete and block masonry wall surfaces are suitable for service and work areas, they are not appropriate finishes for living space. It has therefore become common practice to cover concrete and block masonry walls with a layered finish of gypsum wallboard or panelling. In many cases, a secondary stud wall is installed on the inside of the foundation walls to accomodate insulation, electrical wiring and wall finishes. No such secondary walls are required with PWF systems.

While the practice of building a secondary wall inside the primary exterior foundation walls is functional, it is less than ideal. It reduces the useable space within the basement and compounds the cost of the wall assembly.

Concrete slab and suspended wooden floor systems in basements are in themselves adequate for service and work areas. However, they are generally not adequate finishes for living space. Fortunately, floor coverings can be applied to both concrete and wooden substrates to match the quality of floor finishes in living space on the upper floors of a house.

In conventionally framed houses, ceiling finishes are required to cover the underside of the exposed first–floor joists. While the ceiling finishes in basements can match the quality of the ceiling finishes in the upper floors of a house, due consideration must be given to maintaining access to the utilities that pass between and through the ceiling space.

Although infrequently used, precast hollow core slabs offer the architectural advantage of not requiring a layered ceiling finish. Utilities can also be installed within the cores. The underside of these slabs can be texture–sprayed to provide an economical ceiling finish.

Proprietary truss–joist systems also offer the advantage of accommodating utilities, within the ceiling system. However, the underside of these systems must be covered with ceiling finishes in the same way as conventional wood floor joists. Indeed the need is greater because of the lower fire rating of truss composite joists compared with solid wood joists.

Any new or improved systems proposed for improving basements should give due consideration to the integration of these systems with interior basement finishes. Ideally, the structural materials used for foundation walls, basement floors and basement ceilings should themselves provide an acceptable architectural finish. Alternatively, they should require only a minimal added finish and be compatible with accepted interior living space finishes.

1.7 External Appearance

Conventional deep basements project only nominally above the exterior grade and therefore are barely visible. Consequently, they do not require special architectural treatment. However, in raised basements, a significant portion of the exterior foundation walls may project above exterior grade.

Conventionally formed concrete, masonry and PWF foundation walls that project above grade require some exterior cladding or finish. Many such finishes and claddings have been devised for use with these traditional foundation wall systems.

Any new basement wall systems should ideally be supplied with an integral exterior finish. Alternatively, it should be possible to finish these new basement wall systems using conventional claddings.

1.8 Liveability of Space

For basements to realize their fullest, functional potential, the environment within the basement must be comparable in quality to that of upper floor space. The clear, floor–to–ceiling height should therefore not be less than 7'0" and the living space in basements should be isolated from service and work area functions in the basement.

The basement itself should be serviced with plumbing, heating and electrical services in accordance with the usual standards for living space. Lighting, ventilation and humidity control are of primary importance in basements. Due consideration must also be given to isolating the living space in a basement from noises associated with heating and plumbing systems as well as from noisy activities in contiguous service and work areas.

1.9 Emergency Shelter

Canadian children in some regions have long been schooled to take refuge in a basement in the event of tornados, hurricanes and even nuclear war. Consequently, Canadians have come to expect that basements should serve as emergency shelters in the event of such disasters.

While traditional basements are not structurally designed for this express purpose, experience has shown that basements are indeed often the safest area within a house during catastrophic events. Consequently, any new or improved basement system should ideally continue to allow basements to be used for this purpose. At the very least, advanced basement systems should be structurally sound and unlikely to collapse before the superstructure of a house itself.

2.0 ENGINEERING ISSUES

2.1 Structural Adequacy

The structural adequacy of foundation walls is of paramount importance to basement systems. Basement walls must be able not only to safely transmit the loads transfered to them from the superstructure of a house to the foundation soils, but they must also be able to resist the pressures from the backfill they retain. A diagram that illustrates the loads and reactions that balance the stability of a typical foundation wall is presented in Figure 1.

The minimum building code requirements for the structural design of block masonry and concrete basement walls in North America evolved not from rigorous structural analysis but rather from trial and error experience.

In recognition of the fact that earlier Canadian Building Codes did not explicitly set out criteria for residential foundation designs, the Housing and Urban Development Association of Canada, HUDAC, retained Scanada Consultants Ltd. in 1974 to establish design criteria for basement foundation systems in Canadian housing. This study was triggered by the need to establish design criteria that can be used to design new basement systems on an equivalent basis to traditional foundation designs. The results of this study were published by HUDAC in 1975.

It is significant to note this study suggests that for "average stable soils" basement walls should be designed to resist a lateral soil pressure equivalent to a fluid pressure of 480.5 kg/cubic metre (30 pounds per cubic foot). While this equivalent fluid pressure may appear to be low, it is nearly double the fluid pressure that can be resisted by block masonry foundation walls designed to the minimum requirements of Part 9 of the National Building Code, based upon the maximum tension permitted in such masonry walls under Part 4 of this code. Yet, experience has shown that block masonry foundation walls properly constructed to the minimum requirements of Part 9 of the NBC are structurally adequate.

It is generally assumed that traditional basement wall systems should be designed as a one–way slab that is laterally supported by the basement floor and by the first floor framing. While two–way slab action can be achieved where the length of the basement walls does not exceed twice its height, variations in layout preclude general reliance upon such two–way structural action. It is furthermore assumed that the floors and roof of the superstructure of houses will act as a diaphram to transfer horizontal wind loads to the side walls so that these wind loads need not be considered in the design of basement walls.

The previously referenced study indicates that the combined vertical dead and live loads on foundation walls vary from just over 1488 kg/lineal metre (1,000 pounds per lineal foot) to approximately 3422 kg/lineal metre (2,300 pounds per lineal foot) respectively, for single–storey and two–storey houses with conventional wood–frame superstructures. Moreover, the maximum bending moment in deep basements, assuming an equivalent fluid pressure of 480.5 kg/cubic metre (30 pounds per cubic foot), can exceed 3558.6 N·m/lineal metre (800 foot–pounds, per linear foot) of basement wall.

It is significant to note that the critical loads on basement walls may occur prior to the completion of the superstructure if (as is normally the case) basement walls are backfilled before the superstructure of the house is completed.

For traditional concrete and masonry basement walls, the allowable tensive stresses on the inside face of the wall generally governs the structural design. The critical tension may occur not at the location of the maximum bending moment but at the level of the brick (if the thickness of the basement wall is reduced to accomodate brick veneer). For more flexible basement wall materials such as PWF, the allowable deflection of the basement wall may govern the structural design.

Experience has shown that traditional concrete and block masonry foundation walls can continue to perform adequately (i.e. not collapse) even if they develop structural cracks. However, since cracked basement walls are potentially unstable and cracked foundation walls may permit the entry of moisture and soil gases, they should be designed to be as crack free as possible.

Footings for foundation walls should be designed in accordance with the minimum requirements of Part 9 of the National Building Code, or in accordance with good engineering practice. Results of full–scale prototype tests have shown that foundation walls founded on competent soils may not require footings, if the width of the foundation wall is adequate to reduce the foundation wall loads to pressures less than the allowable bearing capacity of the underlying soils. For example, 4 inch thick precast concrete basement walls have successfully been used in prototype structures without concrete footings.

It is generally assumed that for lateral stability, traditional concrete, block masonry and PWF foundation walls must be laterally supported by the basement floor and the first floor. However, while the first floor lateral support is imperative, frictional forces along the bottom of a footing in combination with the passive resistance of the soils on the inside face of the footing may in themselves be able to provide sufficient lateral support to the base of the foundation walls.

Some Provincial codes permit the use of unreinforced concrete and block masonry for conventional basement walls. However, it is generally accepted that the addition of nominal steel reinforcement is adviseable to reduce the frequency and severity of cracks and to reduce the possibility of catastrophic collapse in earthquake prone areas.

Any new or improved basement wall systems should be as structurally adequate as traditional systems. Until design criteria are explicitly codified, field testing of prototype systems is adviseable. For development purposes, the criteria set out in the previously referenced report offer reasonable guidance. However, foundation walls intended for use in other than "average stable soils" as defined in Part 9 of the National Building Code or with other than conventional wood–framed superstructures may warrant more stringent structural design requirements.

2.2 Durability

Although no explicit standards have been set for the durability of basement systems, it is obvious that basements should be at least as durable as the superstructure of a house. Since experience has shown that conventional, wood–frame housing in

Canada, built even before the advent of proper building codes have remained in service for more than a century, it could be argued that materials used to construct modern basements should remain durable for an equivalent period. However, public acceptance of preserved wood foundation systems that offer a 60 year warranty suggests that many home buyers may be prepared to accept basements with a substantially lesser warranteed life.

Both concrete and block masonry have withstood the test of time, both in North America and in Europe. With modern technology, it is reasonable to conclude that, provided reasonable care is exercised in the construction of basements using these traditional materials, they will remain durable as long as the wood–frame superstructure of Canadian houses. Although the track–record for preserved wood foundations is considerably shorter, with continuing research into preservation technology by the wood industry it is likely that the durable life of preserved wood foundations will extend well beyond the 60 year period currently warranteed by suppliers.

The trend towards finishing basements to full living space places greater demands on basement systems to be durable in a broader sense. Basement systems must not only remain structurally adequate but should not deteriorate in such a way as to damage costly interior finishes.

The durability demanded of individual elements of the basement system will continue to increase as long as they remain strongly interdependent. If the foundation walls are structurally designed to retain well–drained soils, then the drainage system must be capable of draining these soils for the full life of the basement system. Likewise, basement wall insulation applied to the exterior of foundation walls must also remain durable and not loose its insulation value prematurely.

New or improved elements of the basement system should strive not to become the weak link in the basement wall assembly. The more they are relied upon by other elements of the system, the more durable they will be expected to be.

2.3 Moisture Control

When the basement was just an unheated cellar, it generally did its modest job well and allowed the house above to do likewise. The cellar served ideally for storage of root crops and adequately for firewood or coal. While commonly damp or wet (not uncommonly with standing water for weeks or months at a time) it rarely humidified the house to troublesome degrees in that its cool surfaces maintained low vapour pressures and slow transfers to the air; the cool, dense air itself tended to lie stratified, with minimal mixing with the air in the house above. Fungi were generally plentiful, radon undoubtedly in some areas as well, but the house air and structure often remained relatively unaffected by the moisture and conditions under the house.

External Moisture

The cool cellar's "protection" of house and occupants from soil moisture and worse was generally improved further with the advent of the cellar–based furnace and flue. The flue draft pulled in outdoor air through the sill–header and upper foundation wall zone, with air flow down the walls and across the floor. The air flow picked up much of the soil–based moisture and pollutants and carried them directly outdoors through the flue. The cellar did its job; the house stayed above it all, except for sill deterioration in some cases where the wood structure was too close to wet earth or rubblework.

The airleakiness of the house itself was also a strong factor: older houses on cellars are usually very leaky, and their generous air change rates play a substantial role in removing moisture, whatever its source. However, the remarkable strength of the cold cellar factors alone – cool surface/low vapour pressures, and outdoor air flows through the cellar and up the flue – can be seen in many examples today. The presence of a water soaked but cool basement under nearly airtight houses does not usually result, by itself, in excessive humidity and attendant moisture problems in the house proper; especially not where an active flue draws from the basement.

Heated Basements: The effort to gain liveable space by heating the basement changed the picture dramatically. Where moisture can enter a heated basement too freely, the basement itself will likely be plagued with moisture problems affecting its finishings, furnishings and liveability, as will the house above. A warm damp basement is a powerful humidifier. Particularly where the house uses flueless heating, it can be seen that the rates of moisture entry that were common and innocuous in unheated cellars or basements do produce unacceptable problems in and above a heated basement, unless the overall air change is maintained at energy–wasting rates through the heating season. This is scarcely an acceptable solution.

The realization that moisture is not compatible with the new idea of the basement as liveable space has been expressed early and often. Quoting C.R. Crocker in NRC Canada's Canadian Building Digest No. 13, January 1961:

> "The practice of finishing basements is relatively new. Basements in older homes were often small, damp and poorly lighted, accommodating the heating plant and fuel and providing good storage conditions for fruits and vegetables. The basement was not consid– ered acceptable as a play area for children or as a storage space for unwanted or un– used items of furniture, clothing and toys. More recently, with the popularity in Canada of the one–storey bungalow, basements are large and well lighted but not always dry. Many of these basements are being finished in a variety of ways to provide additional living space. Regardless of how the basement is finished, however, it is essential that the basement be dry if it is to serve as useful space."

The moisture problem in (and from) underground structures is a stubborn one. Quoting C.R. Crocker again, from NRC's CBD No. 161 in 1974:

> "The concrete or concrete block basement wall still presents problems. The primary concern of the designer and builder has until now been to meet structural requirements. Less attention has been given to the control of moisture, air and heat flows. The standard design has often failed to provide this control, mainly because of the compromises that must be made with a wall that is partly underground. The occupants of most buildings, however, have come to expect that this underground space will be acceptable for

> normal activities as other spaces. In the meantime, the incidence of dampness, musty smells, rotting wood and flooding in basements is so high and the consequences so unpleasant that every effort should be made to construct a basement that will be trouble free."

The problem of summer condensation adds to the considerable difficulties of maintaining living space below grade, soundly and economically. A final quotation from CBD 161:

> "Finally, it should be pointed out that not all dampness is due to improper design or construction. Ventilation of basements during hot, humid weather, particularly in late spring and early summer, often leads to condensation on cool wall and floor surfaces. The solution is to limit ventilation during such weather and to dehumidfy under particularly severe conditions."

The Crocker papers and others showed an appreciation of the principles involved, and the difficulties inherent in avoiding the "moisture trap" created when insulating below–grade on the inside of the foundation. They remain the guide on trying to do that soundly and economically. Nevertheless, they perhaps understate both the probability and gravity of failures, and underplay the fact that the whole house, given low air change, can be overloaded with moisture from a heated basement where moisture entry has not been excluded with more than traditional zeal.

The presence of fungi in the basement itself was not then considered such a threat to the occupants as it is considered now, but merely a threat to the service life of wood insulation and finishes. The threat from radon and other pollutants in "soil gases" was unknown. There was some experience, and strong concern, with rotting wood and wet insulation in the interior application on basement walls.

The issues now are seen comprehensively. Control below– grade moisture thoroughly enough and economically enough to make sense of utilizing below–grade space as affordable living space (since there is little other reason to have it there) and to protect the energy– efficient house above and in the process, control or eliminate the entry of soil gases as well.

Advances in basement technology must address no other issues of greater importance than those just named. The traditional form and placement of basement structure, insulation and moisture/gas isolation and removal must be looked at freshly and objectively with economics as well as technical elegance always in mind. The advances in technology must follow, or at least respect, these fundamental considerations:

- Nullify or reverse inward–acting water pressure around the basement.
- Nullify or reverse – or provide for reversal in case it becomes necessary – inward–acting "soil gas" pressure (this is discussed further under "Radon and Soil Gas Exclusion").
- Reduce the water vapour pressures in the soil, or reverse the inward–acting water vapour pressure gradient, by keeping the soil cold.

- Avoid excessive condensation in the structure and finishes by keeping them warm in winter and summer, and/or by rigorous installation of a vapour retarder on the indoor side and provision of venting or diffusion to the soil or outdoors on the exterior side of the retarder.

Construction Moisture

Apart from the issue of controlling soil moisture and indoor moisture over the long term, concrete basements raise a short–term issue that must be faced. The dissipation of construction moisture is in sharp conflict with either the use of full–height interior insulation, or the business of finishing a basement expeditiously for quick turnover of the completely finished house. In–situ concrete, interior insulation and rapid turnover just do not mix.

Concrete basement walls and floors are large sources of evaporable moisture that can influence the basement environment for a considerable period of time after a basement is built. This is a factor that can contribute to high relative humidities in unfinished basements, and to undesirable moist environments (encouraging fungal growth, wood rot and deterioration of finishes) within finished basement wall and floor assemblies.

During the hydration process, each gram of Portland cement combines with approximately 0.23 grams of water. This suggests that a minimum water–cement ratio (w/c) of 0.23 should be adequate for complete hydration of cement. However, the volume of hydrated cement is approximately 2.13 times larger than that of cement.

Consequently, it is generally accepted that a minimum water–cement ratio of 0.36 is required to provide sufficient space for all the hydration products, provided water is available from external sources to hydrate the cement completely. In the absence of such external water, a water–cement ratio of 0.42 is required for complete hydration.

However, in actual practice, concrete batched for basement walls and floor slabs, typically has a water–cement ratio of between 0.45 and 0.55. The surplus water that is not required for the hydration of the cement is required to enhance the fluidity and workability of the concrete so that it can be placed, consolidated and finished.

The excess water that is batched into the concrete walls and floor slab of a basement for workability (i.e. slump) is evaporable water that will diffuse out of the concrete slowly, unless all exposed surfaces of the concrete are completely sealed.

In a typical concrete basement having a floor plan of 9 metres by 17 metres with 200 mm thick walls and a 100 mm thick floor slab, the total evaporable water in the freshly placed concrete can exceed 2,500 litres. The rate at which this evaporable water diffuses from the concrete is a function of the mix; the drying environment; and the geometry of the concrete mass.

When applied to the drying of porous solids, Fick's Second Law states that the concentration of moisture in a porous solid will decrease with time at a rate that is directly proportional to its diffusion coefficient and inversely proportional to the square of the moisture particle's nearest path to an exposed surface. Empirical studies have shown that the moisture diffusion coefficient of concrete can vary significantly and may be a nonlinear function of the rate of hydration. However, by assuming a typical value of 0.025 cm*2./day for the diffussion coefficient, it can be calculated that a typical 200 mm thick concrete basement wall which is dampproofed from the exterior and fully exposed on its interior to room temperature air with a 50% relative humidity, can retain 50% of its evaporable water for more than 2 years after it is cast. A 100 mm thick concrete floor slab dampproofed on its underside exposed to comparable conditions can retain 50% of its evaporable water for more than 6 months.

The foregoing calculations confirm that evaporable water in concrete basement walls and floor slabs can contribute considerable moisture to the environment of a newly constructed basement, even if they are isolated entirely from external moisture. If the interior of the walls and the floor slabs are exposed to the interior of the basement space, this moisture can be controlled through dehumidification and/or ventilation. However, if trapped within finished basement wall and/or floor assemblies, this moisture can promote hidden fungal growth and wood rot that is both difficult to diagnose and costly to remedy. Field test results suggest that this is happening with full–height interior insulation and finishing. Where the basement is constructed of site–cast concrete, construction moisture is one more reason to place the insulation on the exterior and let it be a highly permeable free–draining type.

2.4 Energy Efficiency

In the latter part of the 1950's, the realization grew that the practice of operating the basement at warmer temperatures (if only by heat from the floor above plus perhaps token supply from a warm air duct) contributed substantially to the household heating bill. As attention was focused on reducing the bill, the losses through the uninsulated foundation above grade and the first foot or two below grade were belatedly noted and roughly calculated as 25% or so of typical total bills. The case was made strongly for insulating that upper wall zone, but probably little more than that if economics and the very limited knowledge of below–grade losses were both to be respected.

Researchers began to understand by the mid–1960's that such upper–zone interior insulation is appreciably "short–circuited" or bypassed by heat flow from below, (i.e. by heat passing into the soil below the insulated portion and thence upward to and through the cold soil above). The heat flow through the uninsulated lower part of the basement wall is actually increased by the presence of upper wall insulation in that manner, and also because the whole basement runs warmer. The overall energy–conserving efficacy of the insulation is reduced appreciably. The open core "flues" in concrete block walls allow more substantial bypassing, with convective loops as well as through–flow of air carrying heat outdoors.

These and other below–grade losses proved difficult to calculate or model. Early efforts to model them by computer failed rather completely. The soil's heat sink effects, phase change and water–cooling effects are just a few factors complicating the analysis. The challenge to measure and monitor the losses was then taken up in parallel with the modelling, and both the "Mimic Box" calorimeter and the computer modelling began to clarify the picture rather well by the early 1980's. The issue of determining below–grade heat losses has apparently been resolved adequately.

An equally important issue remains poorly resolved. What is the heating demand (i.e. the heating bill) due to the below–grade losses, and what then are the economics of how much insulation and coverage to use? What is the "heating season" below–grade, and how much "free heat", as distinct from paid–for heat, is in play in the basement as the house above? Lacking resolution of these essential points, Canada's authorities and practitioners have split two ways on the matter of insulating basements:

- The building codes have continued to accept 600 mm below grade as adequate. Builders generally stick to that, often with the insulation so loosely applied and poorly protected that bypass losses render it little more than token.

- The "super–conserver" advocates have continued to derive or support heating demand "models" that exaggerate the basement demands (among others) and thus appear to support the case for extreme amounts of insulation over the entire wall height at the least.

A fair case can indeed be made for extending the wall insulation down almost to the basement floor level. The basement floor in deep basements need not and perhaps should not be insulated. The returns in money and comfort are negligible, and in any case it appears wise to allow some heat flow under the footing zone to prevent frost and promote drainage.

Apart from the energy issue, the builders' loose application of code–minimum insulation invites upper wall condensation, icing and mould in some instances, albeit avoiding year–round entrapment. The conservers' full–height application of closed–in insulation invites such entrapment and rotting unless rigorously well executed and/or operating in rather dry soil and low indoor humidity. These points have been considered in the preceding discussion on moisture. It is apparent that the main question to be addressed by advances in basement insulation technology is not about energy conservation but about moisture and gas control – about insulation placement for ideal control – as will be addressed next.

The primary issue to advancing basement technology may therefore be to put insulation where it should be (outside the wall structure) and thereby use it to keep the structure warm, stable, dry, above the interior air's dew point in winter as well as summer; acting as a drain (or allowing draining outboard of the wall and the insulation proper); restricting heat losses essentially everywhere, with little thermal bridging or losses; and to do it economically to rationalize below–grade space as affordable living space.

2.5 Radon and Soil Gas Exclusion

The issue of contamination of indoor air from soil– based pollutants has attracted considerable attention in recent years. Radon by itself justifies such concern in some regions, but fungal spores, pesticides and organic pollutants may also be drawn into the basement by way of infiltrating "soil gases", and these may merit at least as much concern as radon on a more widespread basis. Testing and survey work has begun only recently.

The house generally operates in a slightly depressurized mode through much of the winter, tending to draw in soil gases wherever there are leakage paths below grade. That infiltration coincides with low overall air change rates: the modern house is relatively airtight above grade and is, of course, operated with windows shut and heat energy conserved. Therefore the winter condition may often be one where a significant proportion of the minimized supply of "fresh" air is actually made up of soil gases, or outdoor air passing through the ground on its way indoors.

This may still be air of acceptable quality: The main air flow from outdoors to the entry points below grade may be rather direct, following the easy path provided by the shrinkage gap between the upper part of the soil and the foundation wall. Sustained air flow along this path cools the adjacent soil, relieves it of easily accessible water vapour and other volatiles, and then may pick up little more. That may indeed be a saving grace in the natural ventilation of many houses. Nevertheless, recent surveys indicate that radon and other pollutants are excessive in some areas, and advanced basement technologies must certainly face this issue.

Building every basement as a perfectly–sealed boat, or providing a constantly depressurized or pressurized jacket to prevent any infiltration despite imperfect sealing, would be costly indeed. The issue resolves itself again to the economics of prevention: how often, and in what regions and conditions, are present basement construction actually inadequate or apt to become inadequate in keeping harmful soil gases out of the indoor air?

Two preventive measures may be suggested as rational advances in basement construction. One advance must be to make the wall "dampproofing" layer into a barrier layer, in a much more complete and lasting manner than is evident in the usual token pass with an asphalt solution or emulsion. (For at least a generation, the Scandinavians have dismissed that traditional application as feckless "black magic".) At little or no extra cost, except perhaps for the cost of proper inspection which may again be regarded as important in any event, a good water–and–gas barrier film can be installed. More than one material is available to do the job.

The second advance recognizes that the better barrier wall may still be imperfect, and consists of the provision of an external "airway" surrounding the basement structure. If and where needed, on an individual basis or a regional one, the airway can be depressurized, mechanically or perhaps passively, to reverse infiltration to exfiltration and thus eliminate the entry of radon or other pollutants. While the provision of such an airway around all basements would scarcely be justified for this eventuality alone, it should be in place for other reasons in any case. External insulation around the walls can provide thermal insulation, capillary break, drainage and airway, and the granular fill under the floor can serve as a levelling medium, capillary break, drainage layer and airway.

Such an enveloping airway is available for venting/depressurization to isolate the indoor air from soil gases in practically any conditions. There are further design considerations, perhaps chiefly those involved in ensuring all–encompassing depressurization (eg. an airspace pressure everywhere lower than indoor air pressure, which is itself depressurized with respect to outdoor air in winter) without excessive air flow.

Dr. Timusk, at the University of Toronto, has considered this matter as follows: In highly porous soils, as perhaps the worst case, both the soil boundary of the air space and the paths to the surface may be so leaky that exhaust venting of the continuous airspace could involve very high airflows. Fan size, energy consumption, floor cooling and heat energy losses, would be the penalties incurred in trying to use the airspace as a complete safeguard in such a case. In porous soils, therefore, if not indeed in the general case, it may be best to divide the airspace in two. Let the wall footing be the divider, bearing on undisturbed soil with neither granular fill connecting under it nor provision of vent connections through it. Then both parts may be designed to be depressurized with less need or chance of excessive flow:

- The underfloor gravel may be exhausted from one point to maintain a small margin of negative pressure. Especially if the soil is known to be porous, it may be better to position the polyethylene ground sheet under the gravel, so that the latter is bounded by the slab above, the film below, and the footings on all sides. The polyethylene must be sloped to drains.
- Similarly, the exterior insulation (or other wall airway) may be exhausted from another point. Flow restriction (into the airway) may be provided by an external filter cover over the insulation and above grade, a full cladding and cap.

Such depressurization can be set up only where found to be necessary; the costs of providing it everywhere need not be incurred. Even where ventilation is needed, passive ventilation may often suffice.

2.6 HVAC Systems

In the design of residential heating, ventilating and air conditioning systems, certain relaxations are permitted by Code for unfinished spaces such as basements. This relaxation is based on earlier concepts of basements being inferior spaces intended for service, storage and work areas.

Now that basements are being increasingly used for habitable space, these traditional concepts are changing. It is therefore likely that in future years, this differentiation between finished and unfinished spaces will disappear. For example, currently, unfinished basements do not have to be heated to the same comfort level as finished spaces and do not have to be considered as spaces to be ventilated in the winter. The potential cost savings in taking advantage of the lower requirements for unfinished basements however, hardly seems worthwhile, especially in considering the constraints this imposes on the future finishing of this space.

Heating Systems

If future uses of the basement are planned to change it from unfinished space to finished space, these should be considered at the design stage so that when appropriate, certain features can be included during initial construction to reduce the extent of future changes.

For example, if a forced air system is to be used, it would be advantageous to know approximately where future rooms are to be located in order to establish functional locations of the outlets. Otherwise, the outlet locations will have no relationship to the rooms that will eventually need to be heated.

In the design of heating systems, good practice dictates the heat loss from each room or space served be determined so that sufficient heat can be provided for each area of space. Again, if the heating system is installed without knowledge of the future use of the basement, the original basement heating system may need to be completely redesigned and reworked, at the time of renovation. In simple renovations, when the occupant is capable of providing the necessary changes, this may not be too significant. But in more complicated renovations, this could lead to significant extra expense.

Basement spaces are somewhat more difficult to heat to the same comfort levels as upper level space. This is particularly true in the case of warm air systems that distribute heat by ceiling outlets rather than floor level outlets. The colder temperatures of the basement floor and the larger heat sink it creates can cause serious temperature stratification and lead to uncomfortably cold floors. Overhead heating outlets however, are the most convenient and economical to install and for this reason are quite commonly used in heating basement areas.

Where basements are to contain living space, this problem should be addressed at the design stage so the appropriate measures can be taken to improve the heating as much as possible by the installation of floor level heating outlets, floor surface insulation, two–stage furnace blowers (in the case of forced air systems) or a combination of these.

If the basement space is to be developed as a separate dwelling unit at a future date, the additional constraints imposed by the requirements for fire separations and associated fire dampers may well influence the type of heating system to be installed. One might for example, select an electric baseboard or hydronic heating system over a forced air system in the light of the difficulties imposed by required fire separations and sound barriers. This matter is furthur discussed under Section 2.11 of this report.

Ventilation

Until fairly recently, little attention was given to the design of mechanical ventilation systems for houses. Sufficient natural ventilation was obtained through normal air leakage in winter and by operable windows in the summer. As increased emphasis was placed on reducing air leakage in an attempt to conserve energy, the need to provide mechanical ventilation became apparent, both to control the humidity levels and to ensure a healthful environment. Consequently, the National Building Code now requires that a system of mechanical ventilation be provided in each dwelling unit to ensure a specified air change rate. The system can be as simple as an unducted exhaust fan, or as complicated as a specially designed system with ducts to each room incorporating a heat recovery apparatus.

Although current requirements may permit unfinished basements to be virtually unventilated, this is not considered to be good practice; particularly if the space is to be developed as finished space in the future. If the space is to be developed as an auxiliary apartment, then a separate mechanical system would be desireable and should be considered at the design stage to avoid future difficulties.

Basement space, because of its proximity to the soil is subject to soil–gas contamination, including radon gas. (This is expected to be addressed in the next edition of the NBC). The correction of existing problems should concentrate sealing out the source where possible, using additional ventilation – above that which would be required anyway – only as a secondary measure.

Humidity

Since soil temperatures in summer decrease with soil depth, basements tend to be somewhat cooler than spaces above ground. This raises the relative humidity of incoming air to the point where condensation can occur on any surface below the dew point temperature of the air. The greater the ventilation rate, the greater will be the rate of condensation. This may be serious enough to damage floor finishes and moisture sensitive materials stored on the basement floor. Sustained high humidity levels can also cause mildew growth on surfaces not in contact with the floor as well as generate musty odours throughout the basement space.

Basement space can be effectively improved however, with appropriately sized dehumidifiers. These can remove substantial volumes of water and decrease the relative humidity level to the point where such problems do not occur. This is particularly important where the basement space is to be used as finished living space.

2.7 Electrical Requirements

The design of electrical circuits and the location of receptacles in houses are specified in the CSA, Canadian Electrical Code which also forms the basis of provincial electrical regulations. However, the location of lighting outlets and their switches are set out in the National Building Code which is used as the basis for provincial building regulations.

The main justification for regulating the spacing of receptacles is to ensure that there will be a sufficient number installed to discourage the practice of using extension cords or multiple socket receptacles. The maximum distance permitted between receptacles in all finished areas therefore is intended as a shock prevention and fire safety measure. The maximum permitted spacing is based on the length of cord generally provided for lamps and other portable appliances. The location of lighting outlets and their switches however are justified on the basis of accident prevention, as are many other NBC requirements.

Requirements for receptacle locations and lighting are either based on the use of such rooms (eg. laundry and kitchen uses) or simply on the basis of whether or not the space is finished. In the case of unfinished basements for example, there are no limits on the spacing between receptacles. If finished rooms are later constructed, then the CET and NBC requirements both apply as if the room were above ground level.

When basement walls are insulated on their interior (which is the most common practice) the insulation must be protected against damage by the use of panel type material such as plywood or gypsum board which may or may not be interpreted as being "finished". When the basement space is subsequently developed into "finished" space, the protecting panels generally must be removed to install the required receptacles and then reapplied. By planning for the future use of the space, such receptacles can be installed in the appropriate locations during the initial construction. Such planning can also save future costs of relocating lighting outlets as well.

When the basement is to be developed as a separate dwelling however, the problems involved in separating panel board locations, electrical receptacles and lighting outlets are much more complicated. In such cases, the installation of a subsystem to service the additional dwelling unit may not be practical at the time of the original construction.

2.8 Plumbing Requirements

The minimum plumbing fixtures required in dwelling units are specified in Part 9 of the National Building Code. However, how these fixtures are installed and the materials they are required to be made of are regulated by the Canadian Plumbing Code (CPC). The CPC like the NBC is used by most Provinces as the basis for their building requirements.

The code requirements that specify the required sanitary facilities are minimal and in most modern houses are generally exceeded. The NBC merely specifies that where a potable water supply is available, a kitchen sink, lavatory, bathtub and flush toilet must be installed in each dwelling unit. In addition, such systems must have piped water supply for each sink and lavatory.

Since the plumbing drainage is generally run beneath concrete basement floors, relocation of plumbing appliances or the addition of plumbing facilities in an existing basement requires considerable effort. In most cases, the concrete must be removed to provide for the new piping and allow for its connection to the existing sewer line. After the new plumbing is installed, the damaged concrete must be repaired and any damaged floor finish replaced.

Because of the difficulties involved in installing new plumbing beneath such floors, it is fairly common for a home buyer to have the contractor "rough in" the plumbing for a future bathroom during the original construction even if he has no immediate need for a basement bathroom. This type of planning for future needs is particularly important where the basement is to be developed as a future auxiliary apartment. Not only should future plumbing needs be considered for the bathroom and kitchen of the proposed unit, but laundry facilities must also be kept in mind. If the only laundry facilities at the time of construction are in the basement area, then provisions should be made for such facilities on the upper floors of the house when the changes are made. Plumbing for these laundry facilities can also be roughed in during original construction.

When plastic is used for drain and vent piping above grade, it should be appreciated that this may pose problems if future renovations require the construction of fire separations. Since such piping can melt at fairly low temperatures and can contribute to the fire, its use in relation to required fire separations is strictly curtailed.

Although plastic DWV piping may be used on one side of a fire resisting wall, it is not permitted if it penetrates a fire resisting wood framed floor or is concealed within the wall. It is therefore obvious that if the basement space is to be developed as an auxiliary apartment unit, that the consequences of using plastic DWV piping be appreciated. (However, if appropriate test results can be produced to demonstrate that such piping will not interfere with the integrity of the fire separation, this could permit its use).

2.9 Material Toxicity

Wood used for house foundations has a relatively short service life unless suitably treated with a preservative. Although a variety of chemicals exist that can be used to preserve wood in contact with soil, only two are considered sufficiently durable and safe to be used in house foundations.

Ammonium–copper–arsonate (ACA) and Chromated– copper–arsonate (CCA) are the only preservation materials considered by code and health authorities to be appropriate for use in wood frame foundation systems. Of these, CCA is by far the most common. These preservatives are water–born salts which are forced into the wood under pressure. The residual salts remaining after the treatment process are very stable and are virtually unleachable. In this form, both are considered to be relatively non–toxic in comparison with other common preservatives.

While both CCA and ACA preservatives are considered to to relatively safe, all preservatives should be treated with caution. Workers should avoid continuous skin contact with preserved wood, especially where surface residues are present. Inhalation of sawdust by the workmen should be avoided and workers should wash their hands after handling preserved wood; particularly freshly treated wood. Burning of preserved wood scrap or sawdust can release poisonous gases into the air and leave soluble toxic residues in the ashes. Such scraps should therefore not be burned.

While occasional direct contact with preserved wood is considered to present little or no health risk, this is usually only of academic consideration in wood framed basements since the preserved wood is normally covered by interior finishes.

There is some evidence to indicate that biological action on preserved wood as a result of certain fungi or mould growth can produce trimethylar– senic. Although this gas, which has a character– istic garlic odour, has been produced experiment–ally under elevated humidities and warm tempera– tures, field reports of such odours are relatively few. Tests on laboratory animals indicate that the gas is not likely to present a short term health risk at concentrations up to the level of odour detection. However, there have been no known long term health risk assessments. The potential risk of off–gasing due to high methylization of arsonic was assessed by Forintek Canada Corp. in its 1983 report to CMHC. It was concluded that this possibility should present no potential health problems to the house occupants. It was suggested in this report however, that additional basic research would be desireable.

The possibility of producing such gases however, can be reduced or even eliminated if the moisture level of the treated wood is maintained at a reduced level. Emphasis should therefore be placed on appropriate subsurface drainage, including the use of granular backfill or other drainable medium close to the foundation to prevent water from reaching the wall surface.

It should be noted that caulking of the exterior joints between panels and the provision of an impermeable film on the exterior surface of preserved wood foundations are normally required as well and should also help prevent potential moisture problems and the subsequent risk of off– gasing. Should off–gasing occur, an additional line of defense is provided by the interior finish and the vapour barrier required between the finish and the treated wood.

Where preserved wood footings and floor joists are used with wood basement systems, in lieu of traditional concrete footings and floor slabs, the possibility of off–gasing from these sources should also be considered even though the risk would appear to be very slight. (In such systems the joists are treated with CCA or ACA only if they do not have a regular crawl space beneath them, and as a rule, the plywood or waferboard panels exposed to the basement are untreated).

Since the risk of biomethylation is greatly reduced if the wood is kept relatively dry, it is important that appropriate measures be taken to ensure that the granular drainage layer beneath the footings and joists is effectively drained, and will not be subject to periodic flooding. (Unlike the walls, there is no polyethylene vapour barrier between the preserved wood joists and the basement).

The question of toxicity of CCA and ACA preservatives has been studied at length by the U.S. Environmental Protection Agency which reaffirmed the safety of such preservatives in house basements in 1985. However, their use is still subject to certain regulatory controls including the licensing of applicators, worker protection, allowable surface residues, internal exposure limitations, and programs of public education.

In Canada control of pesticides is regulated under the auspices of the Pesticide Section of the Plant Products Division of Agriculture Canada, which specifies the condition for the registration of pesticides. These conditions generally parallel those of the US EPA, although there are certain differences between the two agencies and in the way that they operate.

2.10 Soundproofing

When the basement of a house is an extension of the living space of the dwelling and is not intended to become an auxiliary apartment unit, there is relatively little reason to take special acoustical design measures to isolate the basement portion from the superstructure portion, any more than one would try to isolate the second storey from the first storey of a house. If however, the basement portion is destined to be developed as a rental apartment, it may be adviseable to consider this possibility during initial construction so that future modifications can be kept to a minimum.

The National Building Code (and many of the provincial codes based on it) requires that the construction separating two dwellings in the same building provide a Sound Transmission Class (STC) rating of 45. It is proposed to increase this rating to 50 in the 1990 addition of the NBC.

The STC rating is a rating system derived from the perceived reductions in the levels of audible sound over the audible pitch range of the human voice. The higher the STC rating, the greater will be the resistance to air–borne sound levels.

It should be noted that there are two principal sources of sound generation in buildings. Air– borne sound is due to activities that cause the air to vibrate and generates sound waves in the air (eg. voices, loudspeakers, musical instruments, etc.). On the other hand, impact noise is created when an activity causes direct vibrations in the structure (eg. foot steps, furniture moving, falling objects, etc.). Impact noise transmission is also measured by a single figure rating system but in terms of Impact Insulation Class (IIC) ratings. At present, the NBC does not regulate IIC ratings. Both the STC and IIC ratings are based on laboratory tests of representative building assemblies. Field tests have also been developed for both rating systems as well.

When air–borne sound strikes a wood frame wall or floor, it causes the surface to vibrate. These vibrations are in turn transmitted across the cavity air space (as air–borne sound waves) or directly through the framing members. This causes the surface on the opposite side of the wall or floor to vibrate and transmit sound waves to the adjacent room or space.

Air–borne sound transmission can be significantly reduced by interrupting the continuity of the framing, either by the use of resilient fastenings (eg. resilient channels) or by the use of staggered framing. When staggered framing is used, the framing on one side of the assembly supports one surface and the framing on the other side supports the other surface.

When the continuity of the framing is interrupted either by resilient channels or by staggering the supports, the air–borne sound transmission through the cavity can be further reduced significantly by providing a sound absorbing layer such as glass fibre in the cavity. This reduction is not as significant however, if the framing does not provide a decoupling of the two surfaces.

To have an appreciation of the range of STC ratings provided in common assemblies, it should be noted that a typically framed floor without a ceiling finish would have an STC rating of about 25. With a gypsum board ceiling attached directly to the joists, the assembly would have a rating of between 30 and 35. If, on the other hand, the ceiling was mounted on resilient channels, and a layer of glass fibre installed in the cavity, the rating would be increased to between 45 and 50. If this assembly also incorporates 50 mm of lightweight topping on top of the subfloor, the rating could be increased to over 50. It should be noted therefore that the proposed new requirements (STC of 50) will not be entirely achieved with typical, lightweight wood floor systems.

Effective reductions of air–borne sound can only be achieved if the assembly is relatively air–tight. Relatively minor openings through an assembly caused by defects such as cracks, open joints or through spaces around piping or electrical boxes, can seriously reduce the effectiveness of sound resisting assemblies. The higher the rating of the assembly, the more noticeable the reduction will be.

Noise generating equipment normally located in basements, such as furnaces, pumps, laundry equipment and dehumidifiers may also pose problems if a basement is to be developed for an auxiliary apartment unit. Such equipment may have to be isolated by sound resistent construction from the remainder of the basement. In some cases, the equipment may have to be isolated by mounting it on auxiliary supports (in the case of wood floors) or by isolating duct work from the furnace by the use of flexible connections and/or sound absorbing duct materials.

The transmission of impact noise in basements can be most effectively controlled by the use of soft floor coverings such as carpeting, or compressible resilient flooring on the floor above. Although the use of resilient channels and insulation within the assembly will reduce the transmission of impact noise as well, noise reduction at the source is most effective.

2.11 Fire Safety

Fire safety provisions in basements depend to a large extent on the functions for which it is designed, and whether or not it is considered to be part of the same household as the space above.

Windows

A room used for sleeping for example, must be designed in such a manner that escape is possible through a window if the normal egress routes become untenable in a fire. Normally this require— ment applies only to bedrooms, since it is assumed that occupants would be awake in other rooms and that a fire would be discovered at a sufficiently early stage to permit safe egress by normal door exits. The provisions for an emergency escape route from bedrooms applies to all bedrooms, regardless of their location within a house.

The National Building Code has addressed this issue by requiring that each bedroom have a window designed so that it provides a sufficiently large unobstructed opening to allow an occupant to climb through it to the exterior. The code also requires that a sufficient space be provided in front of such windows (at window wells) to facilitate occupant escape.

Since current architectural preferences dictate that houses be constructed close to ground level to reduce the amount of exposed foundation wall, there is a tendency to design basement windows to be high up and narrow, and to avoid the provision of window wells. This is satisfactory for some basement activities, but can obviously present a potential fire risk if the space is used for bedrooms. If it is known prior to construction that the basement will be used for a future bedroom, the amount of work required to provide adequately sized windows at this stage, will obviously be much less than if they are later retrofitted into the basement.

It should be noted that emergency escape is only one consideration in sizing windows. The NBC also requires that windows be sufficiently large to provide minimum levels of natural lighting for certain uses, based on the floor area of the room served.

Fire Separations

A single family dwelling unit must comply with only relatively few fire safety code provisions. It does not have to be compartmented by fire separations. Within a dwelling, the entire unit is considered to be under a single authority or head of household who is presumed to be able to regulate the activities throughout the unit.

Where a basement is renovated to form an auxiliary apartment unit however, a number of additional code provisions take affect. For example, the basement unit must be separated from the upper unit by a fire resistent assembly. This is most often achieved by the use of special, fire retardent gypsum board protection on the underside of the floor assembly. However, openings through the assembly such as for duct work, plumbing and stairways must be installed or protected in a manner to maintain the integrity of the fire separation.

Egress

The adequacy of the egress serving a basement dwelling unit must also be evaluated. While a single egress serving a basement unit is satisfactory in most cases, if part of the egress is shared with another dwelling unit above it, a second egress may be required for the basement to ensure that a fire in the upper unit will not prevent occupants in the lower unit from escaping.

Building Services

Fuel–fired furnaces can also pose problems if the basement is renovated to contain a separate dwelling unit. While it is usual practice to install furnaces in houses without fire separations, when such a furnace serves more than one dwelling, it should be separated from the remainder of the building in a properly designed furnace room. This not only requires fire resistent wall and ceiling construction around it, but may also require fire dampers where the duct work penetrates the separations. This could be a decisive factor in the choice of heating system to be used (i.e. electric baseboard or warm air).

Additional code restrictions also apply where plastic piping materials penetrate a required fire separation since such materials can destroy the integrity of the fire separation assembly. Knowing in advance whether or not the space is to be developed as an auxiliary dwelling unit may therefore influence the selection of piping materials used in the plumbing system.

Wood Basements

Wood basements are not considered to pose a significant increase in fire risk, per se. Although arsonic gases are released when preserved wood is burned, this is not considered to be a greater risk than would be the case when many other materials are burned.

Where the floor assembly is required to have a certain rating however, the supporting walls are also required to have the same rating. This may require an additional protecting wall membrane, depending upon the type of wall finish used.

2.12 Retrofit Changes

There may be little need or advantage in offering fully finished, liveable basements in all houses, but a premise in this study is:

- the most basic level offered with an advanced basement system — the "no frills" standard — must provide dry, permanently insulated, soundly–surfaced space adequately isolated from soil water and gases encountered on its site and;

- ready for easy upgrading with full wiring, lighting, heating, plumbing and finishing and, at least for certain regions and conditions, retrofitting with more–than– adequate isolation measures.

The issues of "basic" level and retrofitability become a little fuzzy once the above premise is accepted as the starting point. Provision of, or accessibility to, daylighting may be considered as a marketing point. Unless it is achieved simply by raising the basement largely out of the ground (not always marketable, particularly where rows of high two–storey houses already evoke "Berlin Wall" remarks), provision of more daylighting entails costly, fragile arrangements of window wells, grade level skylights or worse. Similarly, it may normally be uneconomical to provide for later expandibility of a basement beyond its original confines (even punching an archway through the wall into an add–on space would merit second thoughts) although something of that freedom might be provided with Preserved Wood and similar foundations.

3.0 BUILDING INDUSTRY ISSUES

3.1 Capital Investment

The home building industry in Canada includes building material suppliers, building contractors and specialty subcontractors. And while many building material suppliers are accustomed to investing capital in manufacturing plants and equipment, many home builders and specialty subcontractors have traditionally operated with a minimum of capital. It is therefore not surprising that each year, many tradesmen, individually and collectively, become home builders as other home builders leave the ranks to become developers and commercial builders.

Most houses in Canada are built not by a single builder with his own forces, but by teams of subcontractors who are hired by a builder or home owner. Many of these subcontractors operate on a show–string budget and therefore have devised methods to do their work without the need for expensive mechanized equipment.

As discussed in Part A of this report, most basements constructed on Canada today are built of concrete. In the larger urban areas, where the greatest volume of housing is built, many concrete forming contractors have purchased proprietary, modular forming systems. These forming systems are generally built of lightweight materials so that they can be assembled and stripped entirely by hand. In more remote regions of Canada, where the volume of housing built is sparse, concrete forming contractors often custom build wooden forms with lumber that is subsequently reused to frame the superstructure of the house.

Specialty contractors who build block masonry and preserved wood foundations also continue to rely heavily on hand labour, assisted only by the most rudimentary power tools.

Although prototype, precast concrete basements have been constructed in various regions of Canada, they have not been used in any large scale housing developments. This is likely due in part to the capital investment required to produce these precast panels in a plant setting. Since specialty concrete basement forming contractors have been able to avoid heavy capital investments in the past, they will likely continue to resist having to make major capital investments in such technology unless driven to do so by competitive pressures.

Any new or improved basement system should ideally not require large capital investments on the part of those segments of the building industry which have traditionally not been required to make such investments. On the other hand, large manufacturers of building materials have demonstrated in the past that they are prepared to make such capital investments provided that it improves their market share and profit margins.

Based on the foregoing, it appears reasonable to conclude that while building material manufacturers would be the most willing to accept new basement technology that requires considerable capital investment, traditional basement building contractors will resist such technical advances unless they can be utilized with little or no additional capital investment being required of themselves.

3.2 Competitive Pricing

The cost of traditional cast–in–place concrete, block masonry and preserved wood foundations varies considerable from site to site across Canada and is a function of the building volume as will as the cost of labour and materials. None of these traditional systems enjoys a clear cost advantage across Canada.

While preserved wood foundations have made considerable inroads in Western Canada, it is generally acknowledged by the wood industry that the popularity of preserved wood foundations cannot be attributed to a consistent cost advantage over concrete or masonry systems.

Likewise, the cost of block masonry foundation walls is still competitive with cast–in–place concrete in some regions of Canada. The decline in use of block masonry for foundation walls can generally be attributed to a shortage of skilled masons. Fewer masons are immigrating to Canada from Europe and the unavailability of local brick manufacturing has generally reduced the number of skilled masons available in both Western and Atlantic Canada.

While competitive pricing is not the only issue against which new and improved basements systems will be evaluated, it will be a prime factor. Large builders of tract housing will likely place the greatest importance of competitive pricing for basement systems. Builders of custom houses as well as do–it–yourself builders will likely place more importance on reliability, quality and east of construction.

3.3 Simplicity of Construction

Advances in basement technology must show respect for productivity, not only as related to the immediate issue of price, as just discussed, but also to the matter of resource usage. Labour productivity and simplicity of construction go hand and hand. The number of trades required should be minimized, as well as the number on site at a given time, the number of "passes" required to complete the various "layers" that comprise the finished basement, and finally the overall person hours on site. Perhaps equally important is the minimization of skilled trades, ultimately to zero. Skilled trades are not eager to dedicate their training to working in the mud and weather; trades generally will eschew such work and hazards and their hourly price will reflect this more and more.

Simplicity of construction will tend to be expressed in these terms:

- Minimum number of operations, passes, layers. Each layer should serve more than one function.
- Minimum number of parts and pieces: largest (lightest?) panels consistent with handling equipment, as noted in 3.5 and conditions as in 3.6.

The issue is self–evident: the advanced technologies should be at least as single, and thereby productive, as the best of the existing approaches, and as consistent with optimizing 3.4, 3.5, 3.6, and of course, first cost and ongoing costs. Not the least of the incentives in maximizing simplicity and minimizing the number of parts, layers, passes and trades is the incentive to reduce errors and improve quality.

3.4 Speed of Construction

The issue is, again, simple and self–evident: the faster the site work and turnover the better. Advanced systems should at least better the 4 days and 100 manhours of site work that are consumed in the best of in–situ concrete practice, which is already rather good. Tying up a site is tantamount to tying up plant and increasing the plant capital charge involved in the cost the end product. Much of the "plant" tied up in site work is, of course, in the value of the property itself.

3.5 Availability of Labour and Other Resources

This issue is touched upon in the preceeding sections. The focus here will be on labour and the attendant question of materials handling on site.

Why continue the site–builder emphasis on design for manhandling? The basement operations lend themselves to advancing much further. Assume, as in the foregoing sections, that both skilled and unskilled trades will be increasingly adverse to exposed site work and particularly to heavy and hazardous manhandling. Advanced technologies will, then, lean toward:

- off site prefabrication (at the least, completely tie–less forming systems).
- truck–mounted boom crane handling.

3.6 Year–Round Construction

If the industry is to advance as a product industry, capable of producing and delivering to consistent quality as, when and where needed, it will return to the earlier emphasis on year round construction. Advances will favour, as above, all–dry systems produced off–site. Where on–site "wet" systems evolve to retain their status, they will probably emulate the present prefab form/cast in–situ concrete approach of project builders: "stockpile" the basement structure in the fall, protected with straw, ready for house erection.

3.7 Warranty Commitment of Suppliers

As evidenced by the introduction of preserved wood foundations, builders and home buyers expect suppliers of new and non–traditional building systems to warranty such systems. In the case of preserved wood foundations, the wood industry that supplies preserved wood foundation materials generally warrantees these materials against defects and deterioration for 60 years.

The escalating cost of new houses in Canada will likely cause home buyers to exercise greater caution in their acceptance of new and/or unproven basement materials and systems. Likewise, the increased frequency of lawsuits brought against builders by home buyers may deter builders from pioneering the use of such new basement materials and systems.

The need for warranty commitments for basement materials and systems will likely exceed those expected for other elements of a house because of the strategic importance and relative inexcessibility of the basement system. Experience has shown that defective basements are often both difficult and costly to repair. And, the damages resulting from such defects can extend not only to the interior finishes but also to the superstructure of the house itself.

Based on the foregoing, it seems logical to conclude that new and improved basement systems that are viewed as being non–traditional by builders and home buyers will meet with considerable resistance unless their satisfactory, long–term performance is adequately warranteed by a large company or an insurer who is perceived to have the assets to underwrite such a warranty. Consequently, it may be extremely difficult for a small company to penetrate the marketplace with an unproven and/or untraditional basement system.

3.8 Adaptability to Custom Housing

Unlike their Europeon counterparts, Canadian home buyers have come to expect wide choices in the architectural styling of housing. Current styles include bungalows, ranch styles, split–levels, 1 1/2 storey, and two–storey houses in both traditional and contemporary designs. In recent years, attached housing has also regained some of its popularity, particularly in urban areas where cost of serviced land has risen sharply.

While builders of tract houses often design many superstructure "chassis" to fit a standard basement "frame", variations in terrain and home buyer preferences often prevent standardization of basements. Builders of custom homes have long faced the problems of having to build non–standard basements as well.

Traditional cast–in–place concrete, block masonry and preserved wood foundations, provide home builders the flexibility required to alter the shape and the geometry of basements. The height of these basement walls can be stepped up or down to suit varying foundation wall heights, suitable openings for windows and doors can be provided and the shape of the basement walls themselves can be altered to suit the floor plan of the superstructure. Care must be taken in the case of stepped foundations to account for cross grain wood shrinkage that occurs with new houses – especially if green lumber is used. This can be accomplished by ensuring that regardless of the height of the basement wall the same net depth of cross grain lumber is used between the top of the foundation wall and the first floor. In addition, cast–in–place concrete and block masonry systems can easily accomodate fireplaces, attached porches and brick sills, as required.

Although prototype basements have been built of precast concrete panels, as well as steel and prefabricated wood panels, they do not offer the flexibility or design freedom of traditional built–in–place systems.

Ideally, any new or improved basement wall systems should not unduly restrict freedom of design or they will be limited in their application to Canadian housing.

3.9 Call–Backs

Call–backs to remedy deficiencies in new housing are of concern to all reputable builders. Since industry surveys have shown that basement problems are a frequent and recurring source of complaints, any advances in basement technology should strive to advance performance and reliability.

New or improved basement systems should be capable of being properly installed with a minimum of supervision by tradesmen possessing ordinary skills. These systems should also be capable of being inspected for flaws and defects at the time of installation. Concealed features (eg. joints and connections) that are incapable of being inspected after installation should be avoided.

Since a factory–setting provides greater opportunity for quality and environmental control, prefabricated or precast systems offer advantages over traditional systems that are built–in–place, on–site with little supervision and often under adverse weather conditions.

4.0 MARKETING ISSUES

4.1 Affordability

The affordability of housing is a key marketing issue, particularly in those regions of Canada where the threshold price for new housing has risen well above the affordability level of average families. In Metropolitan Toronto for example, the –average– price of a new house is expected to rise to $250,000.00 in 1989.

Up–scale buyers of new houses who have considerable equity in an existing house are less concerned with affordability issues. Having owned a prior house, they are also more likely to place additional value on houses that offer premium quality.

The cost of basement systems that include integral living space should of course be compared to the cost of similar living space on the upper floors of a house. Liveable basement space should therefore be analysed as a total package (i.e. including all services and finishes).

Ideally, new or improved basement systems should be capable of being built to basic, unfinished requirements at a low initial construction cost while affording home buyers the opportunity of finishing this space at a reasonable price in the future, as their financial circumstances improve and their need for additional living space increases.

The possibility of finishing basement space to accomodate rental space is an interesting concept that may find application in urban centres where the demand for such rental accomodations is high. However, the market for such rental space in new housing has yet to be tested. The marketing success of this auxiliary use concept will depend not only upon marketing forces but also upon building code requirements and local zoning by–law restrictions.

Experience has also shown that basements increase the market value of small houses. Buyers of larger homes with ample upper floor living space tend to place a lesser value on basement space.

4.2 Buyer Acceptance

Home buyers tend to favour traditional materials and systems in housing. Architectural styles in housing, even on a regional basis, change slowly and technology that departs radically from these traditional styles will likely meet with buyer resistence.

New and improved basement systems that compete against traditional systems should ideally be compatible with accepted architectural styles and finishes. For example, in regions of Canada where brick veneer is popular, such new or improved basement systems should be capable of supporting brick veneer.

Prefabricated systems or hybrid built–in–place systems that project above ground level should also be suitably finished or capable of being clad with materials that have been tested in the market place for buyer acceptance.

4.3 Cost

Costs are of course items of primary importance in achieving and marketing affordable basements:

First costs will determine if an advanced basement system is worth developing and pushing, and its ongoing costs will help determine its adoption and marketability in the near term and ahead. The reference costs will be those of established basement systems such as prefab formwork/cast–in–situ concrete (brought to a liveable–space state of completion with reasonable technical soundness and durability).

4.4 Resale Value

It is common in Canada for families to own more than one house in their lifetime. Consequently, astute home buyers are becoming even more concerned about the future resale value of any house they purchase. Bazar features that are likely to appeal to few buyers will no doubt be seen as poor investments in the marketplace.

Adapability of function, quality of initial construction and the state of finish of a basement can materially influence the resale value of a house. Consequently, new and improved basement systems should strive for these qualities. They should also afford future home buyers the flexibility of constructing additions or retrofitting improvements to basements in the future.